XXVIII. *Description of* Parkeria *and* Loftusia, *two gigantic types of Arenaceous Foraminifera. By* William B. Carpenter, *M.D., V.P.R.S., and* Henry B. Brady, *F.L.S.*

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Introduction.

In the "Concluding Remarks" appended to Part II. of my "Researches on the Foraminifera" (Philosophical Transactions for 1856, p. 565), I pointed out that the System of Classification of that group which had been erected by M. D'Orbigny on the exclusive basis of *plan of growth*, was inconsistent with the facts disclosed by a careful study of the organization of the five typical Genera described in my first and second Memoirs: since it had the effect of bringing together Genera whose strongly marked physiological differences required that they should be separated by the widest possible interval; whilst it ranked under different Orders generic types which exhibit the closest physiological relationship. And I then laid it down as a fundamental principle, "that physiological conformity in the condition of each individual segment, as indicated by the *structure of its shelly investment*, is a character of primary importance; whilst the *plan of growth*, that is, the mode of increase in the number of chambers, is a character of subordinate importance." And in the "Concluding Summary" appended to Part IV. (Philosophical Transactions, 1860, p. 569), I further expanded this doctrine, by showing that all the types which I had described might be ranged in two parallel Series: one of them characterized by that peculiar texture of the Shell which had been appropriately designated *Porcellanous* by Professor W. C. Williamson*; whilst the shell-substance of the other has the texture which had been described by the same excellent observer, with equal appropriateness, as *Hyaline* or *Vitreous*. A third type of Shell-structure had been noticed by Professor W. C. Williamson (*loc. cit.*) under the designation *Arenaceous*; the shell being mainly formed, not by a calcareous exudation from the sarcode-body of the animal, but by the aggregation of particles of sand obtained from without, the cement by which these are attached together being all that the animal supplies. These differences in the character of the Shell were regarded by Professor W. as indicative of "physiological differences in the living sarcode, or secreting animal substance, that have at least a *specific* value:" but while expressing (p. xix) a strong opinion as to the unphilosophical nature of M. D'Orbigny's System, he did not propose any substitute for it; and contented himself with ranking *porcellanous*, *vitreous*, and *arenaceous* shells that correspond in general form, as distinct Species of the same genus.

The Arenaceous type having been made an object of special study by Messrs. Parker

* "On the Recent Foraminifera of Great Britain," Introduction, p. xi.

and T. RUPERT JONES, they were led to recognize it as having the same fundamental value in a systematic point of view as the *Vitreous* and *Porcellanous* types; and it was in accordance with their representations, that, in my "Introduction to the Study of the Foraminifera" (1862), this type was recognized as characterizing a *third* great Primary Division of the group. It was pointed out, however, that "to separate all the *Foraminifera* that form Arenaceous shells from those of the Porcellanous and Hyaline types, to which many of them obviously bear the closest affinity, would be a violation of the first principles of a natural arrangement; and yet we shall find that there are certain generic types in which the sandy texture is a character of great systematic importance." In certain genera, alike of the Porcellanous and of the Vitreous series, the *surface* of the true shell is often covered with an arenaceous incrustation; but this is a character that does not justify even specific differentiation. It is only when the *whole thickness* of the 'test' is composed of agglutinated sand-grains, and when "certain assemblages of forms, constituting well-marked generic types, can be uniformly characterized by the possession of Arenaceous shells,—as is the case with *Trochammina*, *Lituola*, and *Valvulina*,"—that we are enabled to recognize the distinctive value of this peculiarity, as marking "a fixed and decided physiological character, the occurrence of which elsewhere is only occasional or incomplete." It was further pointed out that the absence of pseudopodial pores in the shells of this group shows their affinity to be rather with the *Porcellanous* than with the *Vitreous* series, notwithstanding the very close resemblance which some of them present to particular types of the latter (*op. cit.*, pp. 46–48).

At the time that the Chapter "On the Principles of Classification" in the Treatise just cited was passing through the press, I learned with great satisfaction that Professor REUSS of Vienna,—the highest Continental authority upon this group,—had fully accepted the doctrine laid down in my previous Memoirs, that the composition and intimate structure of the Shell are characters of primary importance in Classification, and that little value in comparison is to be attached to Plan of Growth; and that he had communicated to the Imperial Academy of Vienna a Systematic Arrangement based on these principles, essentially corresponding with that which I had myself worked out with the assistance of my able coadjutors (Messrs. W. K. PARKER and T. RUPERT JONES), —except in the retention of the distinction between the *Monothalamia* and the *Polythalamia*, of the validity of which, however, he expressed himself doubtful*. In this scheme, as in our own, the essentially Arenaceous types were ranked together in a distinct group, which, like ourselves, he regarded as allied (in virtue of the absence of pores) rather to the Porcellanous than to the Vitreous series. And having subsequently come to the conclusion (which I had explicitly stated in the Chapter just referred to, § 52) that the distinction between the *Monothalamia* and the *Polythalamia* cannot be maintained, he so modified his scheme in a "Nachschrift," that it came to present a most

* Sitzungsberichte der Mathem.-naturw. Classe der Kaiserl. Akad. der Wissenschaften; Bd. xliv., Wien, 1861, S. 355–396.

singular conformity to that which was contemporaneously set forth in more detail in my Systematic Treatise.—This striking coincidence between the results of the studies independently pursued by Professor REUSS and ourselves, has tended, I have good reason for believing, to procure for them a general reception among Continental as well as British Zoologists, which they might otherwise have been long in gaining.

The *Arenaceous* group, thus definitely constituted, was considered by Messrs. PARKER and T. RUPERT JONES as consisting only of one Family, the LITUOLIDA; under which they ranked the three Genera *Trochammina*, *Lituola*, and *Valvulina*, each of them possessing such a wide range of morphological variation, as to present in their aggregate a most curious series of imitations or 'isomorphs' of true shelly Foraminifera, Vitreous as well as Porcellanous. "It is not improbable," I remarked (§ 205), "that future research may add largely to our knowledge of these Arenaceous forms;" and this anticipation has been remarkably confirmed by the results of subsequent investigations. For whilst a singular variety of *recent* Arenaceous Foraminifera, some of them of large dimensions, have been brought up by the Dredging operations which have been lately carried down to great depths in the Sea, it has been discovered that certain problematical *fossils* of very regular globose form, sometimes attaining 2 inches in diameter, occurring in the Upper Greensand near Cambridge and in the Isle of Wight, and formerly supposed to be *Sponges*, are in reality gigantic *Arenaceous Foraminifera*; and the like character has been recognized in a series of fossils which were some time since brought from Persia by the late Mr. LOFTUS, the striking resemblance of which, both in form and general characters, to *Alveolina*, seemed to justify their assignment to the Foraminiferal type, notwithstanding that their enormous dimensions seemed almost to forbid such a determination.

Being aware that my friend Mr. H. B. BRADY had made a special study of these gigantic *Alveoline* fossils, and had come to the conclusion that they constitute a new and peculiar type of Arenaceous Foraminifera, to which he has given the generic designation *Loftusia*, I thought it likely that he might be able still further to elucidate their structure by a knowledge of the results I had obtained from the examination of the non-infiltrated specimens of *Parkeria*, which I accordingly communicated to him. My anticipations were so abundantly justified by the results of Mr. BRADY's re-examination of the minute structure of *Loftusia* under the new light thus reflected on it (so to speak) from *Parkeria*, that I at once perceived that it would be to our mutual advantage that the descriptions of these two extraordinary types should be associated in one Memoir; and on proposing this to Mr. BRADY, I immediately obtained his cordial acquiescence. For the description of *Parkeria*, therefore, I hold myself responsible, as Mr. BRADY does for that of *Loftusia*; but each of us has verified all the more important parts of the description given by the other.

It will be found that both these organisms depart so widely in general plan of structure from any Foraminiferal type previously known, that they must for the present be ranked entirely by themselves. If only *infiltrated* specimens of the Cambridge fossil

had come under my examination, or if my sections even of the non-infiltrated examples had not happened to display the unquestionably Foraminiferal characters of their central "nucleus," I should have hesitated in referring them to that type on any other ground than the impossibility of finding a place for them elsewhere,—so anomalous is the structure of the concentric layers by which the "nucleus" is surrounded. It may be anticipated, however, that when the attention of Palæontologists shall have been drawn to these fossils, a much larger variety of Arenaceous Foraminifera will be brought to light, some of which may connect the anomalous *Parkeria* and *Loftusia* with types already known. And looking to the remarkable results recently obtained by Deep-Sea Dredging, especially in regard to the persistence, in the deeper parts of the Atlantic Ocean, of Cretaceous types supposed to have long since become extinct*, it scarcely seems too much to anticipate that the more extended prosecution of this inquiry may make known to us living examples of the same group, by the study of which the relationships of *Parkeria* and *Loftusia* may be completely elucidated.—For the present, therefore, I deem it better to abstain from any attempt to assign to them a Systematic rank, which can at best be only provisional.

PARKERIA.

1. More than twenty years ago, there were found by Professor MORRIS, in the Upper Greensand near Cambridge, a number of solid globular Calcareous bodies, about an inch in diameter; the superficial markings on which suggested both to himself and to Professor T. RUPERT JONES the idea that they represent a peculiar type of the *Sponges* so common in that Formation. And although the appearances presented by sections of these fossils did not correspond with the structure of any known Sponge, either recent or fossil, yet they did not suggest any other interpretation; and the question of their nature remained unsolved, until the discovery, between two and three years since, of two specimens which retain their original Arenaceous condition without any material change. The partial display of the peculiar internal structure of one of these by a superficial fracture, having led Professor MORRIS to suspect that they might constitute a new and remarkable type of *Foraminiferal* organization, he kindly placed both the specimens in my hands for examination, together with a number of previously collected specimens solidified by infiltration; giving me full permission to treat them in any way I might think most desirable for the complete elucidation of their characters. And on his surmise proving well founded, he gladly accorded with me in giving to this type a Generic designation which should connect with it the name of our valued friend and coadjutor Mr. W. K. PARKER†.

* See my "Preliminary Report" of the *Lightning* Expedition, in the Proceedings of the Royal Society for December 17, 1868, p. 192.

† Since the above was written, I have learned that Mr. HARRY SEELEY, the Curator of the Woodwardian Museum at Cambridge, had been for several years acquainted with the fossil type I am describing, and had paid considerable attention not only to its internal structure, but also to what he believes to be its specific

2. *General Characters.*—In the two specimens which retain their original Arenaceous condition, the sphere, when laid open, is seen to be formed of a series of concentric layers (Plate LXXII.), composed of *lamellæ* of 'labyrinthic structure'*, partially separated by concentrically disposed *interspaces*, but connected at intervals by 'radial processes' which consist of large tubes that are surrounded (in all except the five or six innermost layers) by labyrinthic structure resembling that of the concentric lamellæ. As every part of the fabric is made up of sand-grains cemented together, it is very easily cut by a fine saw in any direction, so as to display in section the general structure and arrangement of the arenaceous framework. As such sections, however, are very friable, they cannot be made transparent enough to exhibit the details of their structure, except by cementing them to glass with hard Canada balsam (which should be made to penetrate them thoroughly), and grinding them down after having been thus solidified; and the specimens thus prepared are by no means equal to transparent sections of the best infiltrated specimens (§§ 3, 13). But some of the most valuable information afforded by non-infiltrated specimens is to be obtained from the examination of *fractured surfaces*; the concentric lamellæ being readily separable from one another by the introduction of a knife-blade into the interspaces. It has been by combining the information obtained through both these methods, that my able draughtsman, Mr. A. HOLLICK, has constructed the ideal representation given in Plate LXXII.†; which brings together in their actual relations the surfaces obtained by section and by fracture, which are separately represented on a larger scale in Plates LXXIII. and LXXIV.;—exactly as they would be seen if it were possible to remove just those portions of the fabric (and no more) whose absence is necessary to disclose them.

3. In a second set of specimens, the original Arenaceous framework has been entirely consolidated by mineral infiltration, which has completely filled all its vacuities: the infiltrating material is usually *calcareous*; but in one remarkable specimen belonging to the Museum of Practical Geology in Jermyn Street (which I have been enabled to

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variations. On communicating with him on the subject, I have received from him a ready acquiescence in the Generic designation above proposed; whilst, at the same time, he prefers to reserve the publication of the results of his own studies of this type, until after the appearance of my description of it. The series of specimens contained in the Woodwardian Museum presents a very considerable diversity of external forms; but so far as I have had the opportunity of examining their internal structure, their agreement with the globular type on which my own description is based is so complete, as to lead me to regard that diversity as a mere *varietal* modification.

* The term *labyrinthic structure* has been used in my 'Introduction to the Study of the Foraminifera' to denote an irregular aggregation of minute *chamberlets* freely communicating with each other; such as would be produced by the more or less complete subdivision of a *principal chamber* by the growth of partitions intersecting one another in various directions,—as often happens, for example, in the Arenaceous genus *Lituola* (*op. cit.* § 214). This kind of structure presents a considerable resemblance to that which, in the Anatomy of higher Animals, is termed 'cancellated.'

† Such 'built-up' figures were very successfully designed by my former draughtsman, Mr. GEORGE WEST, in his admirable illustrations to my previous Memoirs on this group.

examine by the kindness of Mr. ROBERT ETHERIDGE), the infiltrating material is *siliceous.* In either case it is instructive to examine sections made sufficiently thin to be capable of being viewed under the Microscope by transmitted light; but whilst in the specimens in which the infiltrating material has been *calcareous*, it has usually blended with the arenaceous framework in a degree sufficient to obscure the precise boundaries of the latter, in the specimen solidified by *silex* each individual sand-grain can be distinguished, and the 'labyrinthic' structure is admirably displayed (Plate LXXVI.). The reason of this difference is probably to be found in the composition of the Sand of which these fabrics were constructed (§ 7).

4. In a third set of specimens the solidification is partial only, the infiltration having extended from without inwards through a greater or smaller number of concentric layers; and in these the original Arenaceous framework of the unconsolidated interior has for the most part disappeared, so that the spheres, when laid open, are found to be hollow, the central cavity being occupied only by loose sand-grains, or being altogether void. In such specimens the consolidated portion is usually very dark and opaque, so that sections can with difficulty be rendered thin enough for being viewed by transmitted light.—It is worth notice that in one of these specimens of which the outer layers have been completely consolidated, these are succeeded by partly unconsolidated lamellæ, and these again by another set of lamellæ whose consolidation is complete; and this alternation repeats itself twice as we pass inwards to the central vacuity, which in this instance has a diameter only about one-fourth that of the entire sphere.

5. The *diameter* of the largest *Parkeria* which I have seen (this being a specimen from the Isle of Wight, in the British Museum) is exactly 2 inches; that of the smallest (the silicified specimen in the Museum of Practical Geology) is ·75 inch. Other specimens range between these two extremes; the average diameter of those I have seen being somewhat less than an inch.

6. The *External Surface* of the silicified specimen is covered with small rounded elevations separated by intervening depressions, so as closely to resemble that of a mulberry (Plate LXXII.); and I am disposed to believe that this is the normal condition of the fabric,—the dissimilar kinds of surface presented by other individuals being probably the result of abrasion. Thus in one of the specimens in my possession, which has not been solidified by infiltration, the summits of the tubercles have been worn off by abrasion, so as to lay open their labyrinthic structure, the surface of the depressed portions remaining unbroken; whilst in another, which has undergone infiltration, the surface is everywhere uniform, as if the tubercles had been rubbed down to the level of the intervening depressions. In some other cases, however, a condition of surface precisely the reverse of the first is observable, the rounded elevations being replaced by depressions which are separated by elevated ridges: and this seems to depend upon the consolidation of the originally depressed portions by infiltration, whilst the tubercles and the areolæ from which they rose continued uninfiltrated; so that abrasion would have the effect of wearing down the latter (as the more friable substance) even below

the level of the former, and would thus cause the solidified portions to project as ridges. —That the infiltrating material might more readily penetrate the substance of the depressed portions than that of the tubercles, will become evident when it has been shown that whilst the latter is the most solid portion of the fabric, being minutely labyrinthic throughout, the former is composed of a mere layer of labyrinthic structure, having large cavities beneath it (see § 17).

7. Although I have spoken of the *Material* of which these fabrics are mainly composed as 'sand,' yet its composition is very peculiar. When a portion of a non-infiltrated specimen is treated with very dilute Nitric acid, a slight effervescence takes place, and the arenaceous particles fall asunder. But when these are treated with stronger nitric acid, by far the larger proportion of them is dissolved; only a small residue remaining insoluble in the strongest acid. Hence it appears (1) that the Arenaceous particles are held together (as in many other Arenaceous Foraminifera) by a cement of Carbonate of Lime, which, however, forms no large proportion of the whole; and (2) that, although Siliceous sand-grains do occur in small proportion, the principal part of the Arenaceous material is *not* siliceous, but (being soluble in moderately strong nitric acid) is probably Phosphate of Lime. This proves, in fact, to be the case; a careful analysis, made under the direction of Mr. H. B. BRADY, having given the following results:—

Phosphate of Lime	59·7
Carbonate of Lime	26·0
Silica	9·0
Iron and Alumina	0·9
Magnesia, Manganese, Organic Matter, &c.. . . .	4·4
	100·0

8. In several of the specimens which have been partially or completely infiltrated, the chamberlets and sometimes even the large interspaces of the external layers are occupied by a substance which presents a green colour alike by transmitted and by reflected light: this probably consists of the Silicate of Iron, Alumina, and Magnesia, of which the ordinary green particles of the Upper Greensand Formation are composed,—these particles, as Professor EHRENBERG* has shown, being really the chamber-casts of *Foraminifera* whose calcareous shells have entirely disappeared.

9. *Internal Structure.*—Proceeding now to the details of the internal structure of these singularly fabricated bodies, we shall find it convenient, as in the case of the discoidal *Orbitolites* (Philosophical Transactions, 1856, p. 194), to distinguish between the *Nucleus* and the *Concentric Layers* that surround it.

10. The *Nucleus*, as shown *in situ* in Plate LXXII., and on a larger scale in Plate LXXIII. (divided transversely in fig. 1, and longitudinally in fig. 2), is composed of a series of chambers, c^1–c^5, which are laid end to end in a rectilineal direction; the series,

* "Ueber der Grünsand und seine Einläuterung des organischen Lebens," in Abhandlungen der Königlichen Akademie der Wissenchaften, Berlin, 1855.

of which the transverse section is somewhat elliptical, having apparently commenced at the small extremity, and having very gradually widened until it ended abruptly at *d**. The chambers are separated by septa, each composed of a single layer, which are extremely sinuous, like those of many *Ammonites*. Of the mode of communication between the chambers, I am unfortunately not able to speak; for although, by a happy accident, the sections of the only two uninfiltrated specimens yet examined, passed through the nucleus in such a manner as to lay it open transversely in one and longitudinally in the other, the portions of the septa traversed by the aperture are not exhibited in either—both the chamber-walls and the intervening partitions appear so perfectly homogeneous in texture, even under a magnifying-power of 80 diameters, that I was at one time inclined to regard them as composed of proper shell-substance, corresponding with that of the Porcellanous *Foraminifera*, and free from any admixture of arenaceous particles,—its soft and friable texture bearing a close resemblance to that of the fossil *Orbitolites* of the Paris Basin. As the like appearance, however, is presented by the walls of the 'radial tubes,' which I have found to have the same Arenaceous composition as the remainder of the fabric (§ 14), I am now disposed to believe that the chamber-walls of the Nucleus are not exceptional in any other respect, than in the fineness of the particles by the aggregation of which they have been built up.

11. The general aspect of the *Concentric Layers* enclosing the Nucleus, as presented by a section whose plane passes through the centre of the sphere (Plate LXXII.), bears some resemblance to the median plane of an *Orbitolite* laid open by the removal of one of its superficial layers. (See Philosophical Transactions for 1856, Plate V., fig. 6.) But this resemblance diminishes on a closer comparison; and disappears entirely when the details of the structure are examined with adequate magnifying-power. For whilst in *Orbitolites* the vacuities are *chambers*, symmetrically arranged in annular series, and communicating with each other by a regular system of circular galleries and radiating passages, which traverse the intervening solid shell-substance that forms the walls of those chambers,—the vacuities in *Parkeria* are merely irregular *interspaces* left between successive *lamellæ*, each of which is composed of a 'labyrinthic' or *cancellated* substance, made up of minute *chamberlets* separated by irregularly-disposed partitions, but freely communicating with each other; and these vacuities are traversed by radiating tubes, which establish a direct communication between the 'labyrinthic system' of each layer, and that of the layers internal and external to it. Each of the concentrically spherical lamellæ of *labyrinthic substance*, together with the *interspace* (traversed by

* There is probably considerable variety in the disposition of the chambers of the Nucleus. In some specimens from the Isle of Wight (contained in the British Museum), which, by the kindness of Mr. Woodward, I have had the opportunity of minutely examining since the above was written, the chambers are more numerous, and the axis of growth is not rectilineal but *spiral*; and in the largest of these specimens the spire actually turns back on itself. The precise correspondence in structure between the Concentric Layers of these specimens, and those of the specimens described in the text, leaves me in no doubt that the direction of the axis of growth of the Nucleus has no essential significance.

the 'radial tubes') which separates it from the lamella that encloses it, may be conveniently considered as *one layer*; and it will be found to be entirely on the differences in the proportions of these two components, that the diversities of aspect presented by the several parts of the sectional plane depend. Thus it will be observed in Plate LXXII., and on a larger scale in Plate LXXIII. fig. 1, that in the twelve concentric layers which surround the 'nucleus,' the breadth of the interspaces is twice or thrice the thickness of the solid lamellæ; but that in certain parts of the outer four of these layers, the solid lamellæ send irregular 'processes' across the interspaces, so that the 'labyrinthic systems' of successive lamellæ are brought into connexion not merely by the 'radial tubes,' but by direct continuity of cancellated structure. These layers are surrounded by a layer (l^1, l^1) of labyrinthic structure unbroken by any interspace, which is equal in thickness to any two of the layers it encloses. We then come to a second series of twelve layers, of greater thickness than the first; the increase being due to the greater development of the 'labyrinthic system' of each lamella, whilst the breadth of the interspaces remains the same; so that the breadth of the interspaces and that of the solid lamellæ are now nearly equal. But we here notice that the interspaces, instead of being traversed by the irregularly disposed 'radial tubes' of the inner layers, are crossed at pretty regular intervals by 'radial processes' of labyrinthic substance, which (as will be shown hereafter) form an investment to the radial tubes; and thus the concentric interspaces that separate the successive solid lamellæ from the lamellæ internal and external to them, are divided into a number of small cavities having little communication with each other. This series of layers is separated by a second thick lamella (l^2, l^2) of labyrinthic substance, the breadth of which somewhat exceeds that of the first. And around this is a third series of seven concentric layers, which closely resemble those of the second, except that the radiating bands of labyrinthic substance are broader, so that the interspaces which they cross and divide form in the aggregate but a yet smaller proportion of each layer. The thick lamella (l^3, l^3) of labyrinthic substance which encloses these, the five ordinary layers by which it is invested, and the yet thicker lamella (l^4, l^4) of labyrinthic substance which forms the exterior of the sphere, correspond in all essential particulars with those already described.

12. Thus we see that in passing from the centre to the circumference of the sphere, we meet with a progressive increase in the proportion which the comparatively solid 'labyrinthic system' bears to the 'interspace-system' of the successive layers; so that the solidity of the fabric as a whole augments with its increase in size. And this seems to be a general character of the type; although there is found to be no constancy, when different individuals are compared, in regard to the number of *ordinary* layers that intervene between the peculiarly thick lamellæ by which the general regularity of the former is interrupted.

13. We shall now examine, in more detail, such a portion of a group of *Concentric Layers* about halfway between the centre and the periphery of the sphere, as may be taken to present the plan of structure characteristic of the fabric generally; after the

study of which it will be found more easy to understand the variations from this plan that present themselves (1) in the *first*-formed layers which immediately surround the nucleus, and (2) in that *last*-formed layer which constitutes the exterior of the fully-developed sphere.—Such portions are shown in transverse section, as seen by reflected light under a power of 25 diameters, in Plate LXXIII. figs. 3, 4; whilst another portion that combines certain features presented separately in the two preceding, is shown in transparent section, by transmitted light, under a power of 70 diameters in Plate LXXVI. fig. 1. In the latter of these figures, to which the attention may be most advantageously directed in the first instance, is seen a succession of four lamellæ (l^1l^1, l^2l^2, l^3l^3, l^4l^4) of labyrinthic substance, separated in the middle portion of the figure by interspaces which are for the most part wider than the lamellæ themselves, but continuous with each other on either side. Each lamella is bordered on its *inner* or *centrad* aspect by a *continuous floor* (fl^1, fl^2, fl^3, fl^4) composed of adherent sand-grains; which completely closes-in the labyrinthic structure along that face, and cuts off its chamberlets from the contiguous *internal* interspace,—as is yet more distinctly seen in another transparent section which crosses the interspaces in the contrary direction (Plate LXXV. fig. 1), and in the opaque sections (Plate LXXIII. figs. 3, 4). On this floor are built up (so to speak) the partitions which intervene between the chamberlets; but these are so far from being complete, that the cavities they surround remain in free communication with each other. There is generally to be observed, just above the floor, a row of openings more regularly arranged than those seen elsewhere (as is best shown in Plate LXXIII. fig. 3); and the disposition of these seems to indicate that they are the cross sections of *passages* running at right angles to the plane of section, like the longitudinal galleries which form the communications between the contiguous series of chamberlets in *Alveolina.* (See Philosophical Transactions, 1856, Plate XXIX. fig. 8, *bb*, *cc*.) The partitions between the chamberlets, which are composed (like the floor) of sand-grains cemented together, have a generally vertical (or radial) direction; but they show no such regularity as would enable it to be said that they are arranged on any definite plan. They are not covered in by any layer corresponding to their floor; so that the chamberlets open freely into the interspace above; and as this lies on their *peripheral* aspect, they must have been similarly open to the surrounding medium, when the layer of which they form part constituted the external surface of the sphere.—The contrast between the *open* or *external* surface of each layer of labyrinthic structure, and its *closed* or *internal* surface, is best displayed by *concentric fractures* separating two contiguous layers; as shown in Plate LXXIV. figs. 1 and 2, 3 and 4, of which a detailed description will be found in the next paragraph.

14. It has been already pointed out, in the account of the general structure of *Parkeria* (§ 11 and Plate LXXII.), that the interspaces between the successive lamellæ are traversed by *radial processes* composed of labyrinthic structure resembling that of the lamellæ themselves; which bring the 'labyrinthic systems' of several successive lamellæ into continuity with each other, as is shown at *rp*, *rp*, *r'p'*, *r'p'*, in the highly magnified section represented in Plate LXXVI. fig. 1. It is only by concentric fractures, however,

whereby the opposed surfaces of the lamellæ are separated from each other, that the form and arrangement of these 'radial processes' can be properly studied; and the appearances presented by the surfaces thus exposed are found to vary, according as the plane of fracture has passed through the middle of the interspace, or nearer to one of the lamellæ. The former has been the case with the pair of lamellæ of which portions of the opposed surfaces are shown in Plate LXXIV. figs. 1, 2; the latter with the pair of which the outer lamella, carrying with it the 'radial processes,' is shown in fig. 3.—In fig. 2, which represents the *external* surface of part of a lamella thus detached, we see the labyrinthic structure *l*, *l*, opening freely into the interspaces; whilst these cavities are separated by a set of projections (*rp*, *rp*) more or less rounded in form, but connected with each other by bridging extensions. These are the 'radial processes,' which have been broken across and laid open by the fracture. The converse aspect is shown in fig. 1, which represents the *internal* surface of the lamella that immediately surrounded the preceding; for its deeper parts, which constitute the peripheral boundary of the interspace, are here covered by an uniform floor, *fl*, *fl*, that cuts them off from the labyrinthic substance beneath; whilst the radial processes *rp*, *rp*, which rise as elevations from this floor, are here less connected together, so that the interspaces form a more continuous system. The interior of the 'radial processes' thus laid open by transverse fracture is found to consist of labyrinthic structure rather coarser and less regular than that of the lamellæ they connect; but in each of them there is at least one large aperture, whilst not unfrequently there are two or even three; and these are the cross sections of 'radial tubes' exactly corresponding with those which are seen in the inner layers (Plate LXXIII. figs. 1, 2) without any investment of labyrinthic substance.—These 'radial processes' have not unfrequently a somewhat conical form, the apex of the cone being applied to the *outer* surface of the enclosed lamellæ (with which its connexion is consequently slight); whilst its spreading base becomes continuous with the inner surface of the investing lamellæ, into the labyrinthic system of which its own cancellated structure opens. Hence, when the plane of fracture passes through the apical portions of the cones (where the resistance to the disruption of the layers is the least), the 'radial processes' remain in connexion with the investing lamella, as shown at *rp*, *rp*, Plate LXXIV. fig. 3; where are also seen the continuous floor, *fl*, *fl*, that cuts off its labyrinthic system from the interspace on its internal aspect, and the orifices, *t*, *t*, of the radial tubes laid open by the fracture.

15. When, however, as sometimes happens, the concentric fracture passes through the thickness of a lamella, instead of through the interspaces and the radial processes which cross them, its labyrinthic system is laid open in the manner shown at Plate LXXIV. fig. 4; where we also see its chamberlets opening into the cavities of the 'radial tubes' *t*, *t*, *t*, which pass into its substance.—This connexion, however, is best brought into view when these tubes are laid open longitudinally, either by fracture or by section; as in the fractured surface shown in Plate LXXIII. fig. 4; where we see that the cavity of the tube *t* is formed (so to speak) by the coalescence of passages from the labyrinthic

system which surrounds its base; and still better in the transparent section represented in Plate LXXVI. fig. 1, where two of the interspaces are seen to be traversed by 'radial tubes' t^1, t^2, which do not form part of the ordinary 'radial processes.' A careful examination of the entire section of which only a small part is here figured, has fully satisfied me of the universality of this communication; notwithstanding that (as at the upper part of the tube t, Plate LXXIII. fig. 4) it often appears to be interrupted,—the fracture or section not having happened to lay open the apertures or passages of connexion. And further, I have been enabled to satisfy myself, by the use of adequate magnifying power, that notwithstanding the smooth *shelly* aspect which the walls of the 'radial tubes' often present, they are in reality built up, like the lamellæ between which they pass, of aggregated sand-grains,—a fact which may be regarded as justifying the like interpretation of the appearance presented by the substance of the Nucleus (§ 10).

16. When a sufficiently high magnifying-power is applied to transparent sections thin enough to bear it, so as to bring into view the forms of the individual sand-grains and the mode of their aggregation, a curious diversity is observable as to both these particulars between different individuals. In the two non-infiltrated specimens I have thus examined, the sand-grains are angular, and are fitted together with marvellous exactness, as shown in Plate LXXV. fig. 2; in which we see, moreover, that each of the partitions, p, p, which separate the chamberlets c, c, is formed of at least three layers of apposed sand-grains. In the specimens which have undergone *calcareous* infiltration, the forms of the individual sand-grains cannot be clearly made out; but in the thickness and solidity of the partitions between their chamberlets, they agree with the preceding. In the specimen which has undergone *siliceous* infiltration, however,—of which the general structure as displayed in section has been already demonstrated (Plate LXXVI. fig. 1),—the application of a higher magnifying-power shows that the individual sand-grains have a somewhat rounded form (fig. 2), and are more loosely fitted together; and further, that the partitions between the chamberlets are formed of only a single layer of sand-grains. Hence the cement furnished by the animal must have probably borne a larger proportion to the sand-grains obtained from without, than it did in the spheres of which the component sand-grains are so closely fitted together that there seems no room for any uniting medium; and the arenaceous structure of this individual must have been far less solid and compact than that of any of the other specimens yet examined. The difference in the form of the sand-grains must have been pretty certainly due to difference of locality, this specimen not having been obtained with the others, but forming part of a distinct collection. Whether the difference in general solidity had any relation to the nature of the material employed, can of course be only determined by the examination of other specimens whose component sand-grains exhibit the same character; but it seems a *possible* supposition that as the *rounded* form of the sand-grains must have required more cement to unite them, a limitation in the quantity of this cement capable of being furnished by the animal might have prevented it from aggregating the number of sand-grains which are found in such close apposition

in the more solid fabrics.—It is difficult to conceive the means whereby the pseudopodial filaments projected by the sarcode-body, which must have been the instruments employed to collect the sand-grains, were enabled to fit them together with a precision that could not be exceeded by the most dexterous mason, employed to build up angular stones of every variety of shape, with the smallest possible quantity of intervening cement, into a wall of uniform thickness and general regularity of surface. But a precisely parallel case occurs among existing Arenaceous *Foraminifera*, as I have elsewhere shown*.

17. Notwithstanding the apparently well-marked difference between the structure of the layers now described, and that of the earliest layers represented in Plate LXXIII. figs. 1 & 2, we shall find this difference to consist almost entirely in the *proportions* of the component structure. The labyrinthic substance in the latter case presents itself in an almost rudimentary condition, the *lamellæ* being very thin, whilst the *interspaces* between them are very wide, the entire thickness of the *layers*, which are composed of lamellæ and interspaces taken together, being about the same as elsewhere. The width of the interspaces, and the absence of the labyrinthic structure which elsewhere forms the 'radial processes,' makes the 'radial tubes' very conspicuous; and they are somewhat more closely set than in the outer layers. The first trace of labyrinthic substance is seen in the wall of the Nucleus itself, alike in transverse and in longitudinal section (*l*, *l*, figs. 1, 2, Plate LXXIII.); from this, as from a base, spring a number of hollow pillars, the 'radial tubes,' whereon the first of the investing lamellæ is supported, of which the cancellated structure is scarcely more developed; and this again serves as a base for another set of radial tubes, that support a second lamella in which the cancellated structure is somewhat more obvious.—In the *transverse* section (fig. 1), we see that the earlier layers do not pass completely round the nucleus, their disposition being somewhat excentric, as is very commonly the case with the earlier zones of *Orbitolites* (see Philosophical Transactions, 1856, pp. 217, 218); it will be seen, however, on reference to Plate LXXII., that the regularly concentric arrangement is soon established in this direction. In the *longitudinal* section (fig. 2), however, the earlier lamellæ are seen to be considerably less complete, enclosing but a small part of the length of the nucleus; which does not seem to be encased at both its extremities, until four or five of such incomplete lamellæ, each extending somewhat further than that which preceded it, have been formed upon the surface of the elongated primordial chambered cone. Proceeding further outwards, we find the concentric lamellæ progressively increasing in thickness, in consequence of the augmented development of their labyrinthic structure, while the interspaces are proportionately narrowed; and we see the labyrinthic system of one lamella occasionally putting forth irregular outgrowths, which cross the interspaces (usually clustering round the 'radial tubes'), and become continuous with the labyrinthic system of the succeeding lamella. Towards the outer part of this series of layers, which ends with the first *thick* lamella (l^1, Plate LXXII.), not only does the thickness of

* 'Introduction to the Study of the *Foraminifera*,' § 213, and Plate VI. fig. 41.

the labyrinthic substance of the lamella come to equal that of the interspaces, but its peripheral extensions exhibit increased regularity, and become the 'radial processes' already described as characteristic components of the subsequently-formed layers.

18. Passing now to the *outer* or *last-formed* portion of the sphere, we find it to consist of a solid layer of cancellated substance, resembling the solid layers (l^1, l^2, l^3, Plate LXXII.) by which we have seen the regular growth to have been previously interrupted, but of greater thickness and coarser texture (Plate LXXIV. fig. 5). Its inner surface is bounded, like that of the ordinary lamellæ, by a continuous floor (*fl*, *fl*, *fl*) which cuts off its chamberlets from the neighbouring interspaces (*int*, *int*); but its labyrinthic system is connected with that of the lamella it encloses by the radial tubes (*t*, *t*); and these seem to extend through nearly the whole thickness of the layer, each being the centre, as shown in Plate LXXV. fig. 4, of a group of chamberlets disposed around it (like the cells clustered round the vascular canals in an ossifying cartilage), with all of which it is probably in direct or mediate communication. If each of these tubes (as appears probable) served as a centre of growth, conveying a stolon-process of sarcode from the subjacent lamella, it may be readily conceived that the group of chamberlets which surrounds it would project from the general surface, at any rate during the period of most rapid increase; and that thus would be produced the tuberculated aspect, by which, as already stated (§ 6), the specimens that seem best to represent the original condition of the organism are characterized. It may be considered not improbable, however, that the intervening depressions were subsequently filled up by the growth of the cancellated substance, so as to constitute one uniform surface.

19. The strongly marked dissimilarity between the fabric of *Parkeria* as now described, and that of any FORAMINIFERA previously known, whether recent or fossil, renders it impossible to predicate with certainty what was the precise relation of the sarcode-body of the animal to its Arenaceous 'test.' Looking to the manner in which the earliest cancellated lamellæ are attached to the surface of the original chambered cone, it cannot, I think, be doubted that the sarcode which occupied the latter spread over its exterior, as in *Foraminifera* generally*; and that it was by this layer of sarcode that the walls of the first labyrinthic structure were built up. The mode in which each subsequent cancellated lamella was formed, however, not in immediate superposition on that which preceded it, but separated from it by a considerable interspace, and only connected with it by the 'radial tubes,' is not so easily conceived. That each of these tubes contained a 'stolon-process' from the sarcodic substance of the previous lamella, may be considered next to certain. And the manner in which the chamberlets of the succeeding lamella are grouped around the extremities of the 'radial tubes,' seems to indicate that the extensions of these sarcodic 'stolon-processes' furnished the instrumentality by which the materials were collected and arranged for rearing the walls of those chamberlets. It is difficult, however, to conceive (1) how the solid *floor* was laid, upon which those walls were built up (§ 13), if this floor was entirely destitute of support from beneath; and (2)

* 'Introduction to the Study of the *Foraminifera*,' §§ 33–36.

how, if the laying of this floor was effected by the junction of peripheral extensions formed around the extremities of independent 'radial tubes,' its surface should possess the regular continuity by which we find it characterized. In the somewhat analogous case of *Tubipora musica*, it is well known that the transverse lamellæ connecting the polype tubes at intervals, which are formed by lateral extensions from the several tubes whose vertical growth sustains an occasional interruption at those points, are far from exhibiting such regular continuity. And with the knowledge we have of the general indefiniteness and polymorphism that prevails among the various groups included under the RHIZOPOD type, it seems still less to be expected that the multitude of 'radial tubes' proceeding from one lamella of *Parkeria* should all *simultaneously* cease to extend themselves longitudinally, and should give off lateral processes with such perfect uniformity that their coalescence should form a continuous lamella exactly concentric with the preceding, though connected with it only by the hollow pillars which traverse the interspace. On the other hand it is to be remarked that, as all the chamberlets of each lamella open freely on its exterior, the surface of that lamella, whilst as yet uninvested by a subsequent growth, may be presumed to have been covered by a continuous layer of sarcodic substance, in freest connexion with that which occupied its own labyrinthic substance. And it would seem not improbable, therefore, that the continuous imperforate floor of the superposed lamella should have been laid by the instrumentality of this layer upon its own surface; which must then have been completely cut off by it from direct connexion with the surrounding medium. Such communication must thenceforth have been only maintained indirectly, through the 'stolon-processes' occupying the 'radial tubes;' the extensions of which, spreading themselves out on the external surface of the floor of the new lamella, would build up the walls of the chamberlets, and would occupy their cavities,—becoming in their turn the base of a new sarcodic investment of what would then be the external layer of the sphere, which, in due course, would itself be enclosed by another lamella, of which the imperforate floor would be modelled on its own surface.

20. The question naturally arises whether each sarcodic layer, when it had completely floored over the interspace it may be supposed to have filled, continued to occupy that interspace; or withdrew itself into the labyrinthic system of its own lamella, and then projected itself through the radial tubes into the labyrinthic system of the next. To this question no positive answer can be given, since no recent organism is known, in which any analogous arrangement exists. But the former of the two alternatives seems to me the more probable, on the following grounds. If the sarcodic segments were withdrawn from the interspaces, their place must have been taken by some other material; since that a *vacuum* should have been left, is of course inconceivable. How *air* could have found its way into them, is scarcely more conceivable; since these organisms must have been living, like recent Arenaceous Foraminifera, on the bottom of the sea, probably at a considerable depth. If any direct communications had existed between the interspaces belonging to different layers, and between those of the penulti-

mate layer and the exterior, it might be thought not improbable that these interspaces were filled with water from without, and constituted a kind of aquiferous system. But since it may be certainly affirmed that no such passages existed, and that the interspaces had no other communication with the exterior than through the systems of radial tubes connecting the labyrinthic systems of successive lamellæ, which must certainly have been occupied by the sarcode-body of the animal, there was no provision for the admission of water to the interspaces, or, if it did enter to replace the sarcode on its withdrawal from them, it must have remained stagnant in these recesses. If, on the other hand, the interspaces remained full of sarcode through the whole life of the organism, there is no difficulty in comprehending that, though cut off from direct communication with the exterior, the sarcodic segments of the interspaces would share in the vital activity of the entire composite mass. Knowing what we do of the semifluid condition of living protoplasm, and of the interchange which is incessantly taking place between the component particles of the segments, however numerous and segregated they may be, into which the sarcodic body of one of these aggregate organisms is divided, there is not the least difficulty in understanding how nutritive material might have been conveyed through the radial system into the innermost *penetralia* of the sphere of *Parkria*, notwithstanding their investment by any number of concentric layers, however thick*.

Explanation of the Plates of Parkeria.

PLATE LXXII.

Ideal representation of the internal structure of *Parkeria*; the different parts shown in Plates LXXIII. and LXXIV. (from actual specimens) being here combined so as to show the relations of those parts to each other. In the upper transverse section, of which the plane passes through the centre of the sphere, the general arrangement of the concentric layers around the primordial chamber-cone is displayed; and the interruption of the ordinary alternation of solid lamellæ and interspaces crossed by radial processes, by the interposition of the four thick layers l^1l^1, l^2l^2, l^3l^3, and l^4l^4, is shown. The details of the structure of the layers immediately surrounding the chambered cone are represented on a larger scale in Plate LXXIII. figs. 1, 2; and the details of the structure of the thick layers are shown in Plate LXXIV. fig. 5.—In the vertical planes, A

* In my Memoir on *Orbitolites* (Philosophical Transactions, 1856, §§ 12, 34) I showed that the entire disk, however numerous may be the concentric zones of which it is formed, is occupied during life by the sarcodic body of the animal, which continues to fill even the primordial chamber; notwithstanding that this chamber and the zones that surround it are in but very indirect relation with the exterior, through the pores of the peripheral zone. And since the above was written, I have obtained from the Deep-Sea Dredgings of the *Porcupine* Expedition (1869) a complete confirmation of the view taken in the text. For on examining the internal structure of the largest nautiloid *Lituolæ*, I find extensions from each chamber-cavity prolonged into its thick arenaceous wall; which thus presents, though in a rudimentary condition, a labyrinthic structure whose relation to the chamber it surrounds is essentially the same as in *Parkeria*.

shows the *internal* surface of a lamella separated by concentric fracture, the conical radial processes remaining attached to it, as represented on a larger scale in Plate LXXIV. fig. 3:—B shows the appearances presented by a similar fracture which has passed through the radial processes, so as to lay open their cancellated structure, as represented on a larger scale in Plate LXXIV. fig. 1:—C shows the result of a tangential section passing through the cancellated substance of a lamella, as represented on a larger scale in Plate LXXIV. fig. 4:—D shows the appearances presented by the *external* surface of a lamella separated by a concentric fracture which has passed through the radial processes, as represented on a larger scale in Plate LXXIV. fig. 2;—and E shows the aspect of sections taken in a radial direction, so as to cross the solid lamellæ and their intervening spaces, as represented on a larger scale in Plate LXXIII. figs. 3, 4.—Magnified 7 diameters.

PLATE LXXIII.

Fig. 1. Portion of section which has cut the central chambered cone transversely:—*s*, one of its sinuous partitions; *l*, *l*, the first layer of labyrinthic structure, built up on its external wall, around which are seen successive layers of the like structure, separated by interspaces which are traversed by the radial tubes, *t*, *t*, *t*, *t*, one of which is seen laid open at *t'*. Towards the right-hand side of the figure, the progressive increase in the amount of labyrinthic structure in each concentric layer is apparent.—Magnified 25 diameters.

Fig. 2. Portion of section which has cut the chambered cone longitudinally:—c^1, c^2, c^3, c^4, c^5, its successive chambers separated by sinuous partitions; *d*, its termination, with the commencement of the labyrinthic structure shown at *l*.—Magnified 25 diameters.

Figs. 3, 4. Portions of sections traversing the concentric layers in a radial direction, so as to show the manner in which the cancellated structure of each lamella is built up on a solid layer or floor, *fl*, which cuts it off from the interspace, *int*, beneath it. In fig. 3 the manner in which the interspaces are bounded laterally by the radial processes connecting the successive layers is well seen; and in fig. 4 two of the radial tubes, *t*, *t*, contained in those processes are shown laid open, so as to exhibit their connexion with the labyrinthic structure.—Magnified 25 diameters. The free communication of the labyrinthic structure on its outer or peripherad aspect, with the interspace separating each lamella from that which succeeds it, is well seen in both figures; the *lower* margin of which looks towards the *centre* of the sphere, and the *upper* to its *periphery*.

PLATE LXXIV.

Fig. 1. Portion of the *internal* surface of a lamella, separated from that whereon it was deposited, by a concentric fracture which has passed through the radial processes *rp*, *rp*, in each of which are seen one or more large orifices of the radial

tubes. At *fl*, *fl* is shown the solid floor, cutting off the labyrinthic structure of the lamella from the interspace which separates it from the previously formed lamella whereon it rests.—Magnified 25 diameters.

Fig. 2. Portion of the *external* surface of the layer from which the layer represented in the preceding figure had been removed by concentric fracture:—*rp*, *rp*, radial processes; *l*, *l*, labyrinthic structure opening freely into the interspaces.—Magnified 25 diameters.

Fig. 3. Portion of the *internal* surface of a lamella separated from that whereon it was deposited, by a concentric fracture passing through the apices of the conical radial processes, *rp*, *rp*, so as to leave them adherent to it:—*fl*, *fl*, the solid floor, continued over the surface of the radial processes, so as to cut off their labyrinthic structure from the interspaces they bound;—*t*, *t*, orifices of the radial tubes laid open by the fracture.—Magnified 25 diameters.

Fig. 4. Tangential section of a lamella, showing its labyrinthic structure, with the orifices *t*, *t* of the radial tubes cut transversely or obliquely.—Magnified 25 diameters.

Fig. 5. Radial section of the thick outer layer (Plate LXXII. l^4), showing its coarsely labyrinthic structure, in the midst of which are seen the orifices of radial tubes, *t*, *t*, and which is separated by the solid floor *fl*, *fl*, from the interspaces *int*, *int* beneath.—Magnified 25 diameters.

PLATE LXXV.

Fig. 1. Transparent section of part of a lamella taken in a radial direction; showing its labyrinthic structure cut off on its internal or centrad aspect from the interspace int^1 which separates it from the previously formed lamella, by the interposition of the solid floor *fl*, *fl*; while on its external or peripherad aspect it freely communicates with the next interspace int^2, which is bounded peripherally by the internal floor, *fl'*, *fl'*, of the next lamella.—Magnified 30 diameters.

Fig. 2. Portion of the same section enlarged to 250 diameters, to show the arrangement of the sand-grains of which the framework is built up:—*p*, *p*, *p*, section of partitions, enclosing the chamberlets *c*, *c*; *fl*, *fl*, part of the floor of the labyrinthic structure.

Figs. 3 and 4. Portions of thin tangential sections of lamellæ of an infiltrated specimen, viewed as transparent objects; showing their cancelli grouped around the radial tubes, whose orifices are seen at *t*, *t*. The interspaces are occupied by crystals of calcite.—Magnified 30 diameters.

Fig. 5. Portion of a thin transparent section of an infiltrated specimen, showing the appearances it presents under a magnifying-power of 15 diameters. On the *left* side the section traverses the layers *tangentially*; and the labyrinthic structure of the lamellæ, the transverse sections of the radial tubes, and the

interspaces filled with crystals of calcite, are obvious. Towards the right side the section comes to traverse the layers *radially*; and we see the connexion of the labyrinthic structure of the successive lamellæ by the radial processes, between which lie the interspaces filled with calcite. The solid floors separating the superposed lamellæ from these interspaces are well seen at *fl*, *fl*.

PLATE LXXVI.

Fig. 1. Portion of a radial section of a specimen infiltrated with silex, showing the details of the structure of the concentric layers:—l^1l^1, l^2l^2, l^3l^3, l^4l^4, four successive lamellæ, showing their labyrinthic structure, built up on the impervious floors fl^1, fl^2, fl^3, fl^4, and opening above into the successive interspaces int^1, int^2, int^3; at *rp*, *r'p'* are seen the radial processes by which these interspaces are bounded; and at t^1, t^2 are seen two of the radial tubes laid open longitudinally.—Magnified 70 diameters.

Fig. 2. Portion of the preceding enlarged to 250 diameters, to show the arrangement of the component sand-grains.

Loftusia.

21. The extraordinary nature of the remains of Foraminifera discovered within the past few years in the Palæozoic rocks of Canada, has in many ways affected previously received views concerning the testaceous Rhizopoda. In no respect is this so manifest as in the increased importance accorded to the whole group, on account of the *size* of its newly added members. On the first separation of the Foraminifera from the Mollusca, *minuteness* was regarded as a distinctive character of the suborder; and though it was found necessary to place the *Nummulites* in a systematic series, which consisted otherwise of microscopical organisms, they were looked upon as exceptional, in point both of magnitude and of complexity of structure. The discovery in recent times of specimens belonging to larger types, such as those dredged off the coast of Borneo by Sir Edward Belcher, and subsequently described by Dr. Carpenter under the generic name *Cycloclypeus**, scarcely excited sufficient attention to affect the general idea that the group was composed of animals of insignificant dimensions; and it was not until the announcement and description by Dr. Dawson, of Montreal, in 1864, of *Eozöon Canadense*, that the views of Naturalists became modified as to the size attainable by a class of animals of so simple an organization. It is perhaps not too much to say that the controversy respecting the Protozoic, or at least the Animal, origin and characters of the remains of *Eozöon*, though eventually centering in questions of minute structure, would never have arisen at all, but for doubts initiated by the dimensions of the fossil. To those who have made the lower forms of animals their special study, the peculiar arrangement of the calcareous shelly layers on an acervuline plan of growth, already well observed in other types of Foraminifera, whilst it accounts for the irregular and asymmetrical external

* Philosophical Transactions, 1856, p. 547.

contour of the Canadian fossil, equally explains the indefinite extension of the shell-masses.

22. The addition of *Receptaculites* to the list of probable FORAMINIFERA, and the suggestion that *Stromatopora*, *Archæocyathus*, and some other obscure fossils, hitherto regarded as SPONGES in the absence of any very accurate knowledge of their structure, may find their nearest allies in the same category, are indications of a field of research from which great results may be anticipated. At the present moment, therefore, any investigations tending to throw light on what may properly be termed the *gigantic* types of Foraminifera have greatly enhanced interest.

23. Amongst the fossils collected by the late WILLIAM KENNETT LOFTUS, during his Archæological and Geological researches near the line of the Turko-Persian Frontier*, were certain somewhat obscure bodies, oval or fusiform in shape, and occurring in sufficient abundance to give a special character to the rock in which they were imbedded. As they bore a general resemblance to some forms of *Alveolina*, a well-known genus of Foraminifera, from which, indeed, they seemed to differ in point of *size* rather than in any structural peculiarities revealed by a cursory examination, they were assigned by their discoverer to that genus; and, having attracted but little subsequent attention, have been left by Palæontologists in the same position.

24. In Mr. LOFTUS's memoir† these fossils are spoken of as specimens "of a gigantic species of *Alveolina* 3 inches in length;" but no further mention is made of them. Messrs. W. K. PARKER and T. RUPERT JONES, in one of their earlier papers on the "Nomenclature of the Foraminifera"‡, make a passing allusion to them. Amongst their notes on the fossil forms of *Alveolina*, especially those of the Nummulitic Period, they say, "The largest we have seen was collected in Persia by the late Mr. W. K. LOFTUS, and is three inches long and an inch and a half in diameter." The two sentences quoted appear to comprise all that has hitherto been written on the subject of the present paper.

25. A portion of Mr. LOFTUS's geological collection was presented, some time after his decease, to the Museum of the Natural History Society in Newcastle; and finding amongst other things a number of examples of this supposed *Alveolina*, I asked, and readily obtained, permission of the Committee to make such preparations from them as might be requisite for the elucidation of their structure.

26. A very slight examination by means of transparent sections convinced me that, notwithstanding a general similarity in external contour, the internal structure was distinct in many important characters from either of the previously known genera of fusiform FORAMINIFERA. In *Alveolina* the shell-wall is opaque, homogeneous, and Porcellanous; in

* Mr. LOFTUS's collections were made in the years 1849–52, during the progress of a Joint Commission appointed by the English, Russian, Turkish, and Persian Governments for the demarkation of the Turko-Persian Frontier.

† "On the Geology of Portions of the Turko-Persian Frontier and Districts adjoining," by WILLIAM KENNETT LOFTUS, Esq., F.G.S., in Quart. Journ. Geol. Soc. Lond., August 1855, vol. xi.; foot-note, p. 285.

‡ Annals and Mag. Nat. Hist., Ser. 3, vol. v. (1860), p. 182.

Fusulina it is Hyaline and perforate; whilst in the specimens under consideration it was found to be of distinctly granular texture, resembling the built-up 'tests' of some of the smoother Arenaceous types. The obvious conclusion was that these singular fossils were widely separated in organization from their supposed congeners, and that they belonged to a new type, which probably bore a similar relation to *Alveolina* and *Fusulina*, that *Trochammina* (*incerta*) bears to *Cornuspira* and *Spirillina*. At the suggestion of my friend and colleague Professor T. RUPERT JONES, I propose the generic term LOFTUSIA for the type, thereby to associate with it the name of its discoverer, my lamented predecessor as Secretary to the Natural History Society of Northumberland and Durham.

27. *External Characters.*—Most if not all of the specimens of *Loftusia* that have been brought to this country, bear evidence of having formed part of a hard, compact, Limestone rock, from which they have been separated with the utmost difficulty. Indeed the process of mineralization in the animal remains, seems to have gone on simultaneously with changes in the physical character of the calcareous marl of which the matrix was originally composed; and the whole has been converted into a uniform subcrystalline mass, resembling some of the "fossil-marbles" of our Carboniferous system, and capable, like them, of receiving a high polish. The rock is traversed by irregular veins of white crystalline carbonate of lime, very similar to the material that has displaced the sarcode in the chambers and cellular portions of the shells. A piece of the limestone with the fossils *in situ* in the Newcastle Collection (Plate LXXVII. fig. 1) shows the condition in which they are found. It has apparently been long exposed to the action of weather, and is thereby a good deal roughened; but still it shows how large a proportion of the rock is composed of Organic Remains, chiefly those of *Loftusia*; and the course which the fracture has taken, right through the fossils at whatever angle they happened to lie, without deviating to follow either their periphery or any of their structural lines, indicates the determined adhesion which exists between them and the matrix. The appearance of the specimens that have been roughly separated on the spot, testifies to the same fact; for scarcely any of them show an exterior surface that can be regarded as satisfactorily representing the shell during the life of the animal. The general external features, however, are readily made out; and we are in no worse position in respect to this, than we were with the analogous genus *Fusulina*, which until a year or two ago was only known from the sections of Limestone in which it occurred; yet the recent discovery of specimens in a free state has done little beyond confirming the accuracy of the conclusions previously arrived at*.

28. In shape the specimens are all oblong or oval; but they vary considerably in their proportionate dimensions. Many of the longer ones taper almost to a point at either extremity (Plate LXXVII. fig. 2); whilst a stouter variety (fig. 3) exhibits obtuse

* [Mr. BRADY here refers to the results I have recently obtained from the examination of specimens of *Fusulina* kindly transmitted to me by Mr. C. A. WHITE, of Iowa, U.S.; which results conclusively establish the correctness of the opinion I had founded on the study of less perfectly preserved specimens, that *Fusulina* belongs to the Vitreous or perforated series, instead of ranking with *Alveolina* (as was supposed by Messrs. PARKER and T. RUPERT JONES) in the Porcellanous or imperforate series.—W. B. C.]

rounded ends and a much shorter conjugate axis. The two largest perfect examples that have come under my notice* have about the same weight (three ounces); and their dimensions represent fairly, and in by no means an extreme light, the difference in proportion alluded to. Their measurements are respectively $3\frac{1}{4}$ inches by 1 inch, and $2\frac{1}{4}$ inches by $1\frac{1}{4}$ inch. In other words, the proportions between the axis and the transverse diameter are in the long form as 65 to 20, in the short thick variety as 36 to 20. In both of these specimens the transverse section is circular; and others of the same form have proportionate dimensions ranging between the two. There are, however, some few in which the transverse section is not circular but lenticular (bi-convex). These are of smaller size, and resemble an almond in general contour (fig. 4); but whether the peculiarity is the result of compression, or is due to an inequilateral plan of growth, is not easily determined. I am inclined to attribute it, for reasons which will presently be given, to the former cause; the more so as there is no ground for specific or even varietal distinction in the structure of the interior. It may be remarked in passing, that a similar or even wider range of variation in external form exists in the isomorphous genus *Alveolina*. In that group may be found every gradation in shape, from a nearly perfect sphere to a spindle with pointed ends, having a length four or five times as great as its thickness through the centre. Exceptional specimens of *Alveolina*, analogous to the compressed examples of *Loftusia* above referred to, are occasionally though rarely to be met with in Tertiary limestones.

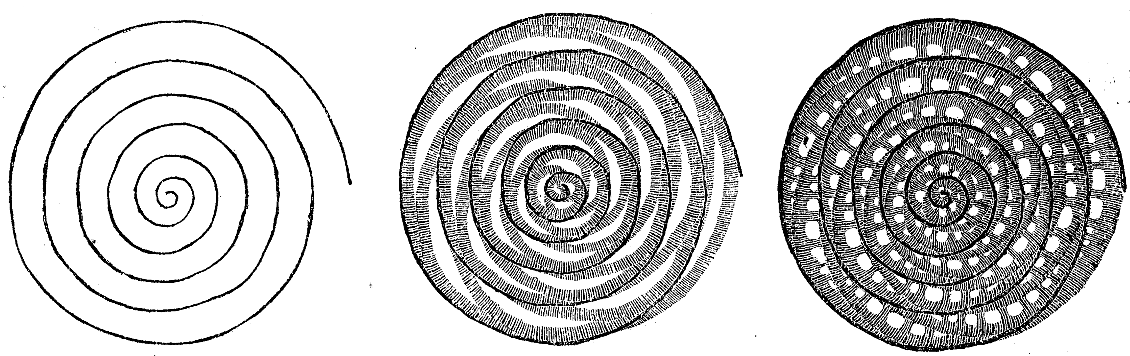
29. As might be expected from the nature of the matrix, the exact condition of the exterior of the test, in respect to inequalities of the surface, ornamentation, or markings determined by structural peculiarities, is not very readily learnt. One or two of the specimens which appear to have been enucleated with less disturbance of the superficial layers than the rest, have a series of tolerably regular furrows, nearly equidistant, traversing the shell from end to end, somewhat resembling the uncut portion of that figured in Plate LXXVIII., though more uniform. These depressions are not so sharply defined nor so deeply excavated as similar lines in the smaller *Alveolinæ*, neither have they the same structural significance. It seems probable that they indicate only alternating periods of more and less vigorous growth, or that they are dependent on external circumstances. Arenaceous Foraminifera generally show but little tendency to the surface-ornamentation common in the Vitreous and Porcellaneous groups; and there is no reason to suppose that, in the living condition, *Loftusia* differed materially in superficial texture from *Trochammina*. Apart from the longitudinal riblets before described, the exterior may have been either quite smooth or slightly granular, according to the nature of the sand of which it happened to be built up, and the proportion of calcareous material which formed the cement.

30. *Internal Structure.*—Although, in general contour, *Loftusia* most closely resembles

* A specimen in the Museum of the Geological Society, London, must originally have been somewhat larger than either of these; but, as it has had sections cut from it for microscopic examination, its exact dimensions cannot now be obtained.

the two genera already mentioned, *Alveolina* and *Fusulina*, its structural relations may be best understood by reference to the lower members of the Rotalian series, such as *Planorbulina* or *Discorbina*, or to the still simpler type *Involutina*. This relationship, though at first sight it may appear far-fetched, becomes obvious upon a comparison of their various sections. It is only necessary to imagine one of the simple Rotalians thickened and drawn out at the umbilici, so that what was before a convex disk should become a cylinder tapering more or less towards the ends; and the analogy is at once apparent. The transverse section of a body so constructed would correspond to the horizontal section of the original disk; and the ideal diagram B would represent equally well the arrangement of the principal chambers in the Rotalian types and in *Loftusia*, as seen in section. At the same time, the lines indicating the septa have in some respects a different significance in different cases. In theory the test of *Loftusia* may be said to consist primarily of a continuous lamina coiled upon itself, like a scroll constricted at the ends. The space enclosed by this 'primary lamina' is divided into chambers by longitudinal septa. The septa are of 'secondary' growth; that is to say, they are not continuous with the principal wall or 'spiral lamina,' but are rather offshoots from it. The chambers separated by the septa are long and very narrow, and extend from one end of the shell to the other. The septa are not perpendicular to the 'spiral lamina' as in *Alveolina*, but very oblique; and they often take also a more or less oblique direction longitudinally. The longitudinal section is in this way somewhat confused, and less to be relied upon than the transverse, in its bearing upon the form and relation of the various parts. The chambers are further divided by numerous irregular extensions of the secondary or septal system, which it may be convenient to regard as subordinate to the rest. These 'tertiary' ingrowths are generally at right angles to the septa, or nearly so.—The diagrams A, B, and C will make somewhat clearer the general plan of structure; but it must be borne in mind that they are purely ideal, and drawn without reference to scale. The first of the three, A, may be supposed to represent a transverse section of the spiral lamina, or 'primary' wall; B shows, in addition, the 'secondary' system to which the septa belong; whilst C indicates roughly the subdivision of chambers by the 'tertiary' ingrowths.

A. B. C.



31. We must now consider these various structures *seriatim*, in relation to the appear-

ances presented by the actual specimens. The process of infiltration, which has in every instance extended to every part of the organism, has obscured its most important peculiarities. Fortunately in the discovery of *Parkeria*, and in the results of Dr. CARPENTER'S researches on this new and most interesting type of FORAMINIFERA, we find a clue to the reading of several portions that would otherwise have remained unintelligible. Many of the specimens of *Parkeria* are completely infiltrated with a subcrystalline mineral, very similar in physical characters to that occurring in the chambers of *Loftusia*. But there are others, which, either from the nature of the matrix, or from the compact texture of the peripheral layer of the test, contain no such deposit; but remain, as nearly as can be judged, in the state of a dead and empty recent shell. In addition to these, a few examples of *Parkeria* have been met with partially infiltrated; only their exterior layers having been consolidated by mineral deposit. Each of these three sets of specimens has added its quota to the facts upon which the elucidation of a somewhat complex organization depends; and each has a distinct value in the study of *Loftusia*. By comparing the appearance of corresponding portions of the infiltrated and uninfiltrated test in *Parkeria*, reliable data are obtained from which to estimate the condition of *Loftusia* prior to the filling up of its cavities with inorganic matter. Constant comparison with the less altered type has been found needful, in order to demonstrate the organization of the more obscure form; and for the opportunity of pursuing the subject in this way I am indebted to the kindness of Dr. CARPENTER.

32. The texture of the 'test' has been stated to be Arenaceous, that is, built up of sand-grains held together by a structureless calcareous cement. It is only necessary to refer to it in this place, in so far as it affects the relation of the walls to the sarcode-cavities. The granules vary considerably in size, but are comparatively much larger than those from which the investment of *Parkeria* is formed; hence in the transparent sections of *Loftusia* the texture does not appear so homogeneous, nor is the outline of the labyrinthic ingrowths so well defined; indeed it is obvious that in the recent condition the interior surfaces could not have had the same smooth finish that is to be observed in the open portions ('interspaces') of *Parkeria*.

33. After careful examination of a large number of sections of *Loftusia*, made on the median line in both a transverse and a longitudinal direction, I find no indication of the existence of a central cavity, or anything resembling the large primordial chamber which is so usual a character amongst the FORAMINIFERA. The tendency to fill up the interior of the chambers with shelly ingrowths, which leads to some of the most striking peculiarities of its organization, is manifest from the very earliest period of life. We have no very young specimens from which to study the condition of the test before it assumes the form and habit of maturity, except such rare instances as may be found in microscopical sections of the limestone matrix, and these are far from satisfactory. One section of the rock, figured at Plate LXXVIII. fig. 5, shows, however, amongst other minute fossils, the transverse section of what I have little doubt is a very young *Loftusia* (*a*). The whole is about $\frac{1}{45}$ in. in diameter, and shows the space enclosed by the first turn of the spiral lamina, and about half the circuit of the layer immediately surrounding it.

The spiral lamina itself has much the same dense opacity as is presented by older individuals; and the interior has, so far as can be made out, a loose, arenaceous texture, which, with a further deposit of cementing material, might be expected to give the sort of structure we find at the axis of the mature shell. But in the absence of evidence from specimens in the intermediate stages, much importance cannot be attached to the characters of a single individual, the original features of which may have been greatly altered in the process of fossilization.

34. In the fully grown examples, the first circuit of the 'spiral lamina' encloses a space of variable dimensions,—in some cases measuring from $\frac{1}{30}$ to $\frac{1}{25}$ inch in diameter at the centre, and from $\frac{1}{8}$ to $\frac{1}{4}$ inch in length, more or less; and the revolutions succeed each other with tolerable regularity at intervals of $\frac{1}{50}$ to $\frac{1}{30}$ inch. From twelve to twenty revolutions are usually found in an adult specimen; but twenty-five have been noticed in one instance, and doubtless even a larger number may occasionally be met with.

35. The 'spiral lamina' or 'primary skeleton,' as it may be regarded, is composed of almost impalpable calcareous grains closely cemented. It is imperforate, and not more than from $\frac{1}{1000}$ to $\frac{1}{800}$ of an inch in thickness. From this extreme tenuity it necessarily depends for support upon accessory structures.

36. The space enclosed by its first revolution—constituting the central axis (Plate LXXX. fig. 2, *c a*)—is occupied by a mass of shell-substance somewhat resembling in general features a piece of fine sponge, but not quite uniform in its structure. Quite in the centre it assumes the form of a network of irregular anastomosing tubes, with the interspaces filled in with shell-substance to a greater or less extent; but nearer the primary lamina, the irregularly disposed growths resolve themselves into a more definite series, and take a uniform direction. The outer portion becomes in fact the commencement of a system of parallel columnar or tubular processes springing from the inner surface of the spiral lamina, and having their free ends directed inwards (Plate LXXIX. fig. 1, *a*, and fig. 2, *a*). This system of parallel tubuli may under favourable circumstances be traced throughout the course of the spiral lamina, except when interrupted by the occurrence of septa; and it forms, as well shown in the figures just referred to, a sort of lining to its inner surface. The two structures are in such close juxtaposition that they appear continuous; and their physiological distinctness is only noticed in exceptional places, when a minute portion of the sarcode appears to have become entangled between them, leaving for a short distance the primary lamina free from the accessory skeleton (Plate LXXIX. fig. 2, *b*, and Plate LXXX. fig. 3, *b*). The nature and extent of the labyrinthic portion of the layers may be best understood from a longitudinal section taken on a line very near the periphery, as shown in Plate LXXIX. fig. 1; for whilst a central section presents all the layers in the same aspect, one taken near the exterior bears a different relation to each consecutive layer. Thus we have about the centre of the figure at *c* the transverse section of the parallel processes just described as lining the spiral lamina; whilst at *a* is seen the lateral aspect of the same. Such a section leaves no doubt as to the tubular character of even the more compact portions of the labyrinthic system.

37. The septa, which divide the space enclosed by the spiral lamina into chambers, are directly connected with the labyrinthic system, and form a part of the accessory skeleton. There is no continuation of the primary lamina as an imperforate facing to them, nor is there any analogous investing organ. The septa are therefore entirely secondary, and are merely extensions of the labyrinthic system, at regular intervals; taking a very oblique direction, and terminating on the outer surface of the preceding whorl. The end of the shell, where, from the greater depth of the layers, and the gradual thinning out of the chambers, the septa form a prominent feature, shows most clearly their cancellated structure and the sort of connexion that exists amongst them. A magnified drawing of this region (Plate LXXIX. fig. 3) bears a strong general resemblance to those portions of *Parkeria* in which the 'radial tubes' are largely developed, though differing in several essential characters. Not only are the cancellated structures of the septa connected, but there is free communication between the adjacent chambers of the same layer. In other words, whilst the spiral lamina is imperforate, the septa have numerous perforations which allow the passage of sarcode-stolons.

38. But neither the cancellated structure immediately lining the primary lamina, nor its septal developments, can be distinguished in any very definite manner from further ingrowths of subordinate importance, which to a greater or less extent occupy the interior of the chambers. These 'tertiary' extensions are of very irregular contour; and being usually built up of the coarsest particles, are less easily made out.

39. Thus whilst the 'primary skeleton,' or what may be regarded as such, is simple and easily understood, the accessory structures are of somewhat complex character, and present appearances very diverse in different specimens, not only from the variable extent to which they are developed, but also in their disposition and texture. Some specimens show scarcely any traces of the accessory skeleton, beyond that already indicated as lining the spiral lamina and forming the septa; whilst there are others in which the sarcode-cavities are to a great degree filled up by its extension into their interior; but in either case some portions of the superadded structure in each chamber are prolonged, until they rest upon its floor. In those specimens which have their cavities least filled up, the ingrowths take the form of tubular columns, which traverse the chambers in a radial direction (*i. e.* perpendicular to the spiral lamina), terminating either on the septum of the previous chamber, or on the exterior wall of the preceding whorl of chambers. In others they are more massive and irregular, and appear to be arranged so as to subdivide the chambers in an incomplete manner into chamberlets. When this latter condition exists, the intersection of the chambers does not take place at regular intervals; but the wide central portion of each is left comparatively open, and the ingrowths increase in frequency as the sides thin out. Transverse sections of the larger specimens present to the naked eye an appearance as of dark spots set at very regular intervals along the spiral band, which on examination are found to indicate the central larger chamberlets in the successive chambers; that is, the wider portions have the fewest intersecting shelly growths. The smaller chamberlets at each side are hardly to

be distinguished, unless magnified, in the general labyrinthic system. This distinction of large and small subdivisions is one of degree only, and is not nearly so striking under the microscope as might have been expected from the appearances presented to the unassisted eye; but it nevertheless does exist, and is a means to an end.

40. The 'accessory skeleton' in *Loftusia* may be regarded as the homologue of the labyrinthic lamellæ in *Parkeria*; although there are important differences, the precise significance of which it is impossible to explain with our present limited knowledge of the relation of the two types. The most remarkable of these is that in *Loftusia* the labyrinthic portions take their rise from the inner surface of the primary spiral lamina, and are directed inwards, that is, towards the central axis; whilst in *Parkeria* the order is reversed, the corresponding structures presenting their free ends towards the periphery. Again, the 'radial tubes' which complicate the labyrinthic system in *Parkeria*, have no precise analogy to any portion of the accessory skeleton of *Loftusia*; the nearest approach to anything of the sort being the lines of tubular communication between the septa of the individual layers, at the ends of the shell, where the layer is thickest; but here, as in other parts, the spiral lamina cuts off direct communication between the layers. The office fulfilled by the accessory skeleton in *Loftusia* is, I conceive, simply that of a support to the primary lamina, imparting the necessary solidity to the organism. The subdivision of the chambers into chamberlets seems to be an accidental circumstance, and has but little bearing on the general economy of the animal.

41. In considering its fitness for this purpose, the various external relations of the organism must be borne in mind. It is manifest that the delicate calcareous lamina, described as the 'primary wall,' would, both from its contour and extreme tenuity, be utterly insufficient of itself to protect a mass of sarcode three inches long and one inch in diameter, or to impart that rigidity which, judging from other examples, is necessary to animals of its class.

42. The layer immediately within the 'primary wall' adds greatly to its strength, not only from the additional thickness it imparts, but also from the connexion its septal prolongations establish between the successive whorls. This portion, however, does not represent a solid mass; and the septal portions are further weakened by irregular perforations for the stoloniferous tubes connecting the sarcode of the adjacent chambers. The columnar extensions of the shell-substance provide direct vertical support; and their distribution on the plan described is that likely to ensure the maximum of strength combined with economy of material. A longitudinal section whose direction nearly coincides with the long axis of the chambers (Plate LXXX. fig. 4), shows the primary walls as parallel lines, and the septa (*s*, *s*) as slightly oblique bands diverging in the most gradual way, and eventually connecting one wall with the other. In the exaggerated view so obtained, the columnar supports (*ts*, *ts*) appear at regular intervals; and throughout the long narrow ends of the chambers they are very close and massive in proportion to the space left for sarcode. As the chamber widens, they diminish in frequency and proportionate dimensions.

43. The tubular condition of the principal part of the secondary skeleton has been inferred from the appearances presented by portions of exceptional specimens in which the infiltration has least obscured the structure. But in the absence of these, there would have been sufficient evidence to be gained from a close comparison with corresponding appearances in *Parkeria*, to demonstrate the general tubularity of the labyrinthic system. This character is foreshadowed in a group of Foraminifera of much simpler type. I have elsewhere* described the occurrence in *Ellipsoidina* (an interesting genus of Foraminifera discovered by Professor SEGUENZA in the Miocene clays of Sicily) of a line of tubular columns, whose only ostensible office is to support a series of chambers which otherwise would have but little connexion with each other. There is a strong reason why the accessory skeleton which forms so large a proportion of the entire bulk of the shell in *Loftusia* should be built up on a plan that would ensure the greatest strength with the least weight. The habit of Foraminifera is to live on the surface of the sand or mud at the bottom of the sea, and recent shells taken from a position entirely beneath the top of the mud are dead and empty;—in point of fact the animal dies if it is buried in the sand. It is clear from the nature of the limestone matrix, that the floor of the sea in which *Loftusia* lived was a very fine calcareous mud, soft and oozy. Now the specific gravity of the material of which the skeleton is built is about 2·7; and sarcode itself may be regarded as but little heavier than water; so that if, as may be supposed, the hollow sinuses were occupied by sarcode, it would materially alter the relation between the specific gravity of the animal and the element in which it lived; that is to say, the mass comprising the shell and the sarcode would be of much lower specific gravity than would be the case were the skeleton solid:—hence the animal would be correspondingly better fitted to preserve its natural habitat. It is not certain, however, that the labyrinthic sinuses were occupied by sarcode, or even that the ends projecting into the sarcode-cavities were open; and it is still possible that they may have fulfilled some distinct functional purpose. In the absence of evidence on this point, it is needless to dwell upon it; but it is within the range of possibility that the cancellated structure may during life have formed a sort of water-system, or perhaps may even have been filled in part with air. These are but surmises that have presented themselves during the investigation; but if either condition existed, it would further reduce the general specific gravity.

44. *Physical and Chemical Relations.*—The condition of this fossil is very unfavourable for the determination of the elementary physical characters of the original organism, owing to the completeness of the mineralizing process to which it has been subjected. The sand of which the test is formed is entirely Calcareous; and its identity in chemical composition with the mineral substance occupying the sarcode-cavities renders it impossible to separate or distinguish the two by means of reagents. We learn also from the study of the different condition in which specimens of *Parkeria* have been found, that the infiltration of a substance having the same chemical composition as the test has a

* Annals and Magazine of Natural History, 4 ser. vol. i. p. 333, pl. xiii.

much greater effect in obliterating its structural characters, and even in obscuring their outlines, than the same process when a different material is concerned. Thus the Calcareous test of *Parkeria* becomes almost devoid of character when its cavities are filled with a subcrystalline calcareous mineral; whilst a specimen having its chambers occupied by silex has lost none of its distinctive characters. Chemical analysis of the infiltrated fossil (*Loftusia*) shows that at least 99 per cent. consists of Carbonate of Calcium, the remaining 1 per cent. being chiefly siliceous matter, a composition representing equally well an average sample of the limestone matrix. The test, therefore, is built up of Calcareous sand-grains, incorporated by a cement of carbonate of calcium. But although the selective power which seems traceable in some Arenaceous Foraminifera, enabling them to choose certain sand-grains in preference to others*, has no exercise in respect to the chemical nature of the constituents of the test, there is still something of the same sort observable in relation to the *size* and *distribution* of the particles which go to its formation. Thus whilst the septa and the looser portions of the labyrinthic structures are coarsely arenaceous, the spiral lamina is composed of exceedingly minute particles. The presence of a number of specimens of the smaller species of Foraminifera imbedded by accident with the sand in which they were living, and now forming a portion of the fabric (Plate LXXX. fig. 3, *f*, *f*), renders it comparatively easy to estimate the size of the sand-grains. The largest that could be satisfactorily measured was about $\frac{1}{100}$ of an inch in diameter; but they seldom attain more than one half this size. Specimens of the same species abounding in the Limestone matrix run to much larger dimensions. One of the almond-shaped specimens of *Loftusia* which appears to have had its walls somewhat disintegrated by pressure or otherwise, presents its constituent granules in a very uniform condition, both as to their general appearance and their dimensions, and in this instance the average diameter is about $\frac{1}{400}$ of an inch. In the more compact portions of the labyrinthic system, the granules are smaller; and as they approach the spiral lamina they become still more minute. In the thin layer which constitutes the lamina itself, a magnifying-power of 500 diameters (the highest I have been able to use with advantage on any section yet prepared) shows the ultimate structure only as a uniform, densely packed mass of particles, individually too small for even approximate measurement. The transparent sections (Plate LXXIX. figs. 4 & 5) cross regions in which the constituent granules are exceptionally small and uniform, and show well their close setting in the compact portions (*sg*, *sg*).

45. The variable external appearance of such of the fossils as have been exposed—through the unequal action of the weather, especially on the fractured surfaces—is pro-

* The question of selection of materials amongst Foraminifera with composite tests is one to which my attention was drawn in a recent chemical examination of subarenaceous *Miliolæ* (*Quinqueloculina agglutinans*) obtained by Mr. Jeffreys from deep water in the Hebrides. Their tests were clearly formed of sand-grains and cement. They occurred in siliceous sand, having but a very small percentage of calcareous matter derived from the *débris* of Molluscan and other shells; yet they were entirely soluble in very weak acid, leaving scarcely a microscopic trace of silica.

bably due to other causes rather than to the size of the constituent sand-grains, and chiefly to two, viz. a slight difference in the character of the subcrystalline deposit in the chambers, and the partial disintegration of the shell-structure from pressure or other disturbing cause, during, or it may be previous to, the process of mineralization. I have noticed that the specimens in which the exposed portions are the roughest and most granular, are those in which the structure is most confused, not merely in the labyrinthic growths, which are naturally of coarser texture, but even in the compactly built spiral lamina, which, usually so well defined, is often scarcely traceable in such individuals.

46. It has been stated that the shells of a number of the minuter forms of Foraminifera are to be found imbedded in the shelly material forming the test, their presence being due to the fact of their having been living amongst the sand in the neighbourhood of the animal whilst the process of building its skeleton was being carried on. Their identification is of considerable importance, as they afford, together with the organisms to be observed in the limestone matrix, the only data by which the depth of water wherein the animal lived, may be indicated with any degree of accuracy. In the test itself the following have been noticed: in many cases it is impossible to do more than identify the Genus, specific and varietal characters often depending on peculiarities not to be recognized in sections.

Biloculina ringens, Lamk.
Biloculina contraria, D'Orb.
Triloculina oblonga, Montagu.
Triloculina trigonula, Lamk.
Triloculina tricarinata, D'Orb.
Quinqueloculina seminulum, Linn.
Spiroloculina planulata, D'Orb.
Trochammina incerta, D'Orb.
Planularia longa, Cornuel.
Textularia sagittula, Defrance.
Textularia variabilis, Will.
Textularia pygmæa, D'Orb.
Bigenerina nodosaria, D'Orb.
Discorbina, sp.
Rotalia Beccarii, Linn.

The specimens seen in the limestone rock are generally of much larger size than those which have been built into the walls of *Loftusia* itself. Most of the foregoing varieties occur, and, in addition, the following,—

Spiroloculina canaliculata, Czjzek.
Valvulina Austriaca, D'Orb.
Cristellaria, sp.
Dentalina, sp.
Bulimina ovata, D'Orb.
Planorbulina ammonoides, D'Orb.
Rotalia Schrœteriana, P. & J.
Nummulina, sp.

The last named is one of the small thick forms characteristic of the lower Tertiary strata.

47. Mr. W. K. PARKER has given me much assistance in these determinations. The conclusions to be derived from them are that the rock is a lower Tertiary limestone, very similar to some of our Miliolite limestones, but richer in the small arenaceous forms;

and that the sea-bottom was a soft calcareous mud, and lay at a depth of from ninety to one hundred fathoms. A few minute fragments of Molluscan shells resembling columns of *Pinna*, and small pieces of fossil POLYZOA, are the only remains that are to be found of animals of higher organization than Foraminifera.

48. *Zoological Relations.*—From the details of structure which have been adduced, the genus *Loftusia* would seem to find a natural place at the head of the Arenaceous series of Foraminifera, a position corresponding to *Alveolina* in the Porcellanous group, and *Fusulina* amongst the Vitreous forms. In texture it is similar to the higher *Trochamminæ*. Its general plan, in so far as the primary skeleton is concerned, is simple; and there is no approach to the more complex organization found in the shell of the Nummulite or its immediate allies. Its most striking external difference from the other members of the Arenaceous group (*Parkeria* of course excepted) is its *size*; and the chief peculiarity of its internal structure consists in the secondary shelly growths necessary for the support of the enlarged test.

49. Notwithstanding great diversity in the size and contour of the specimens, their difference is attributable to degree of development depending on external causes, rather than to specific or varietal distinction; and with a slight reservation in respect to the compressed specimens, I propose to place all under one species, of which the following will serve as a description.

LOFTUSIA, gen. nov.

Testâ liberâ, regulariter rotundatâ, axe elongato; transversè sectâ orbiculari (aut lenticulari?); ex spirâ bene compositâ, cujus orbis quisque orbem antecedentem penitus amplectitur, constante; in numerosissimos loculos septis longitudinalibus partitâ iterum plus minusve subdivisos; structurâ arenaceâ; aperturis (multis, complexis, labyrintheis?).

L. PERSICA, spec. nov. L. *testâ elongatâ, ovatâ vel fusiformi; transversè sectâ orbiculari (vel compressâ?); extremitatibus obtusis aut rotundatis; loculis multis, angustis, interne cancellatis, cancellis ad axem versis; septis perobliquis; aperturis (multis, complexis, super facie ultimi loculi arcuatâ sparsis?); superficie lævigatâ aut subarenaceâ, interdum sulcis subtilibus paribus intervallis inter se distributis in longitudinem sculptâ. Longa,* 1·5 *usque ad* 3·5 *poll. Lata* ·5 *usque ad* 1·25 *poll. Loc. Persia, fossilis.*

Distribution.—In respect to distribution but little can be said beyond what appears in Mr. LOFTUS'S Memoir (*op. cit.*, p. 235) and the notes accompanying the specimens presented to the British Museum and the Geological Society; but the information from these sources is deficient both in Geographical and in Geological details. In describing the geological characters of a section lying "on the direct road between Káláh Túl and Isfáhán," after speaking of a confused series of gypsiferous rocks, which seem "as if the bed had been shot off the side of Mererárí during its sudden elevation," the author adds, "Masses of gravel-conglomerate lie in the bed of the stream and high up the slopes of

the mountain through which the Ab-í-Bázúft flows," and then follows this foot-note:—"A few miles N.E. of this stream (but before reaching the left bank of the Kúran at Dú Púlún) I procured from a hard rock of blue marly limestone a gigantic species of *Alveolina*, three inches in length." The station appended to the specimens in the British Museum and the Geological Society is the "Kellapstun Pass, near Dú Pulún, Bakhtiyari Mountains, Persia." Unfortunately scarcely any of the names mentioned appear on the "Sketch-map" that accompanies the paper; and for scientific purposes the district referred to may be said to be as yet unmapped. I am indebted to Mr. KEITH JOHNSTON, of Edinburgh, for a detailed tracing of the region, procured with some pains from unpublished German sources; from which it appears that Dú Púlún is on the 32° parallel N. Lat., and that a Longitude of 50° 30 E. would indicate a point halfway between it and the little mountain stream Ab-í-Bázúft. The district lies between the N.E. corner of the Persian Gulf and Isfáhán.

50. Our knowledge of the Geological distribution of the type may be summed up in few words. Mr. LOFTUS appears to regard the "blue marly limestone" as belonging to the oldest Tertiary rocks, though he does not say so very distinctly; and the evidence of the Foraminifera imbedded in it leads pretty conclusively to the same view. The data afforded by the Microzoa are probably sufficient confirmation, in the absence of any satisfactory record of larger fossils from the same geological horizon.

In conclusion I have to express the obligation I am under to my friends Mr. W. K. PARKER and Dr. CARPENTER, for the interest they have taken in the subject of the present paper;—to both for suggestions derived from their large knowledge and philosophic views in connexion with the Protozoa generally,—to the latter for light thrown upon obscure points by the study of collateral structures in *Parkeria*, and above all for the opportunity of constant reference to specimens of that genus, without which the history now given could not have been so far elaborated.

EXPLANATION OF THE PLATES OF LOFTUSIA.

PLATE LXXVII.

Fig. 1. Piece of *Loftusia*-limestone, the surface of which has been 'weathered' by exposure, and the sections of the fossils thereby brought into relief (*natural size*).

Figs. 2, 3 & 4. *Loftusia Persica* (*natural size*). Of these figs. 2 & 3 represent longer and shorter individuals of the normal form, whilst fig. 4 is the compressed variety with lenticular transverse section described in § 27. Figs. 2^a, 3^a, 4^a represent the transverse sections of the three specimens drawn to their natural size.

Fig. 5. Section of the Limestone rock forming the matrix of *Loftusia*, with Foraminifera *in sitû*.

a. Young specimen of *Loftusia* cut transversely, showing the space enclosed

by the first turn of the spiral lamina, and about half the circuit of the layer immediately surrounding it.

Sections of several other Foraminifera included in the matrix are seen.

PLATE LXXVIII.

General view of the structure of *Loftusia*, showing the appearances of sections cut on different planes, and their relation to each other.—Magnified about 4 diameters.

PLATE LXXIX.

Fig. 1. Longitudinal section of *Loftusia*, very near the periphery, viewed as an opake object.—Magnified 45 diameters.

s l. Imperforate primary skeleton or spiral lamina.

a. Series of parallel, columnar, secondary shell structure, immediately lining the primary lamina.

c. The same cut transversely.

It must be borne in mind that this is not a central section, but a tangential one cut so near the periphery that the direction of the section differs in its relation to each successive layer, so as to illustrate fully the arrangement of the accessory skeleton. The centre, representing the innermost of the four layers of which portions are drawn, shows at *c* the appearance presented by the parallel columnar shelly processes (*a*, *a*) when cut across. The portion of the figure to the right exhibits a mass of the accessory skeleton formed from overlapping septa, and shows the sort of intercommunication between them. Owing to the direction of the section, or possibly to accidental causes, the spiral lamina (*s l*), the continuity of which is usually a prominent character, appears lost at the end of the layers to the right, though well seen in the other portions of the specimen.

Fig. 2. A portion of a transverse section. *s l* represents the spiral lamina, and at *b* its distinctness from the accessory structures may be noticed. This condition may be found at points in almost every specimen. The nature of the septa, as prolongations of the series of columnar processes (*a*, *a*, *a*) lining the primary lamina, may be easily traced. The subdivision into chamberlets, a large chamberlet (*c c*, *c c*, *c c*) occupying the centre of each chamber (see § 39), is also apparent.—Magnified 45 diameters.

Fig. 3. Longitudinal section of a portion of a layer near the end of the central axis. At this point, where the layer is widest and the chambers thin out and overlap, the intercommunication of the septa is often so regular and complete that it resembles very strongly the portions of *Parkeria* in which the system of radial tubes is most developed.

Figs. 4 & 5. Transparent sections, to illustrate the nature of the subcrystalline calcareous deposit filling the chambers, and the close setting of the sand-grains (*s g*, *s g*) in the compact portions of the test.—Magnified 45 diameters.

PLATE LXXX.

Fig. 1. General view of a transverse section of an average specimen, mounted in Canada balsam and seen as a transparent object, under a low power.—Magnified 5 diameters.

Fig. 2. A similar preparation from one of the compressed specimens alluded to at § 28. —Magnified 6 diameters.

All the almond-shaped specimens are small, possibly not fully grown; and if so, the composite test may have been less consolidated than in mature individuals. This may account for their form. The arrows *l f*, *l f* indicate a line on which pressure at the two sides appears to have caused the fracture of many of the layers.

Fig. 3. Enlarged view of a portion of the transparent section shown in fig. 1.—Magnified 25 diameters.

s l, *s l*. Spiral lamina.

b, *b*. Points at which the 'primary' and the 'accessory' skeleton are not in close approximation, and show their distinctness.

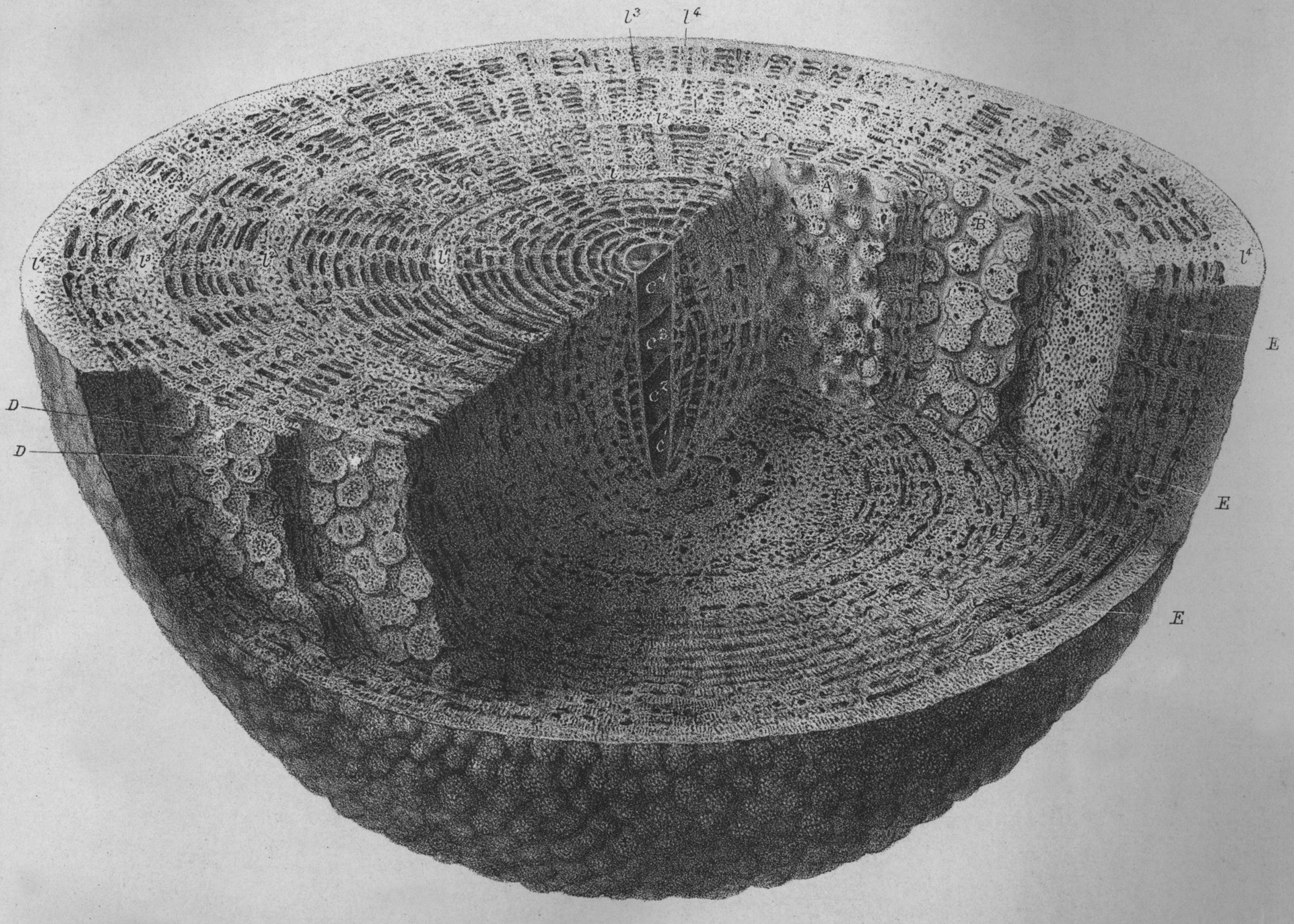
f, *f*, *f*. Imbedded Foraminifera *in sitû*.

Fig. 4. Longitudinal central section of a single layer near the periphery, showing the regularity of 'tertiary' processes subdividing the chambers.

s l, *s l*. Primary skeleton.

s, *s*. Septa.

t, *s*. Tertiary shelly processes affording perpendicular support.



PARKERIA.

A Hollick del. et lith. W. West imp.

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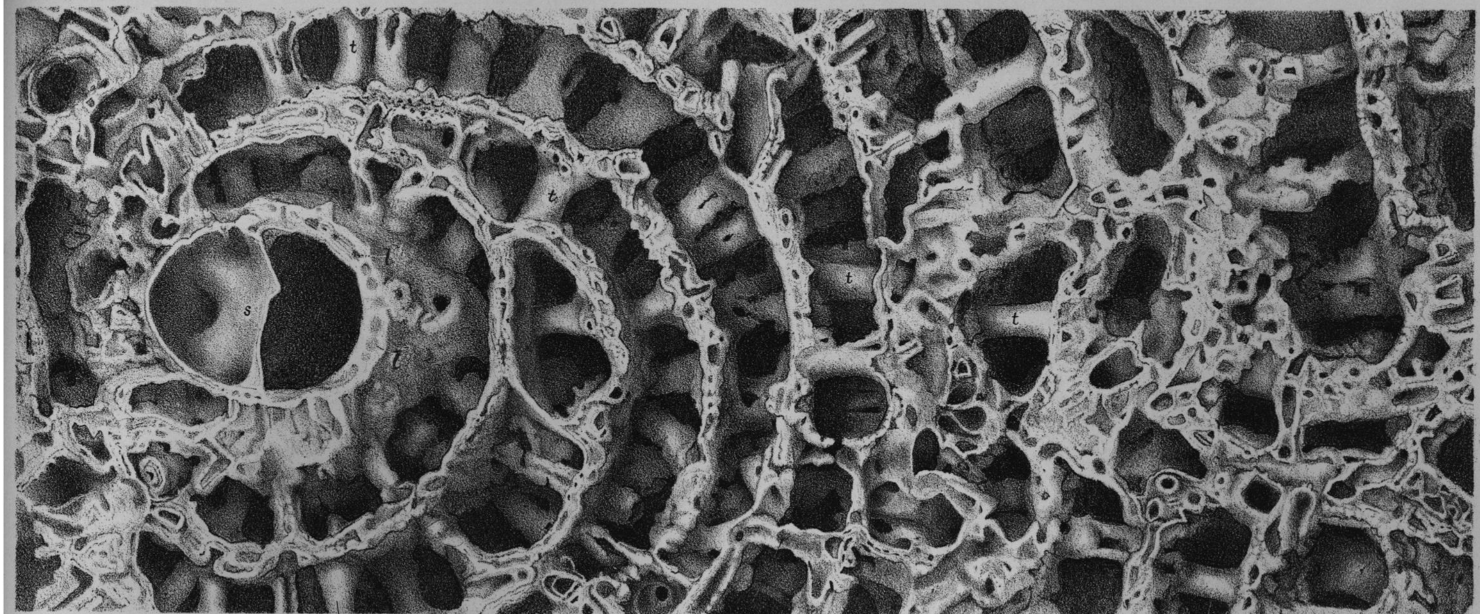

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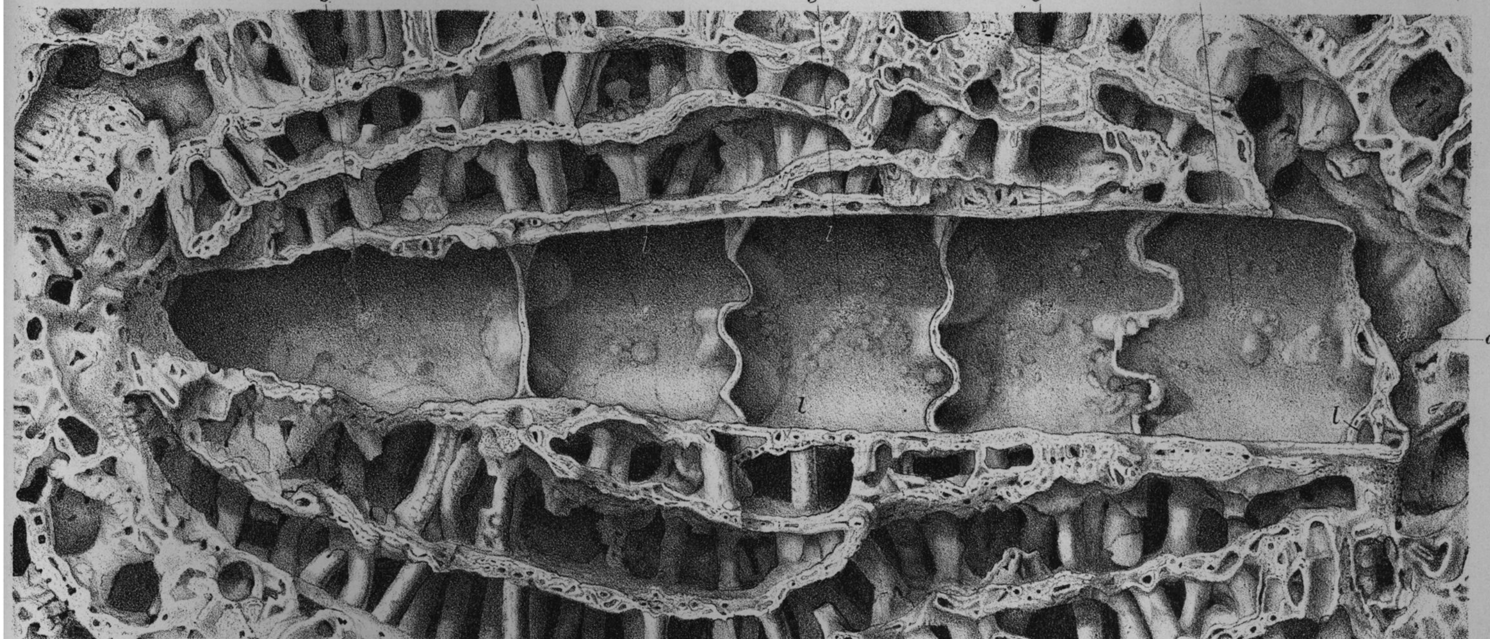

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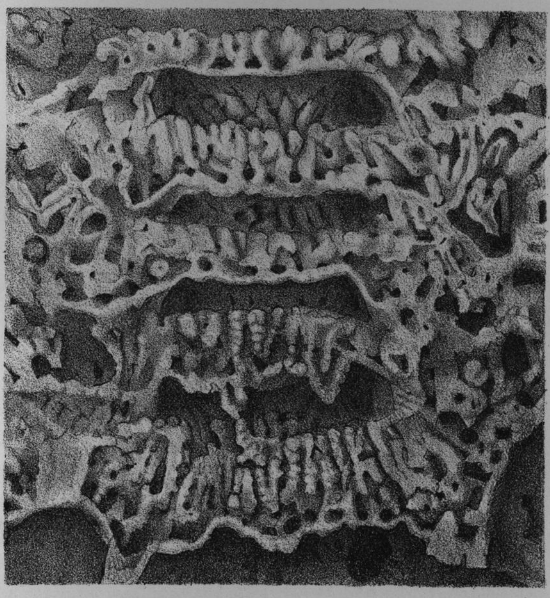

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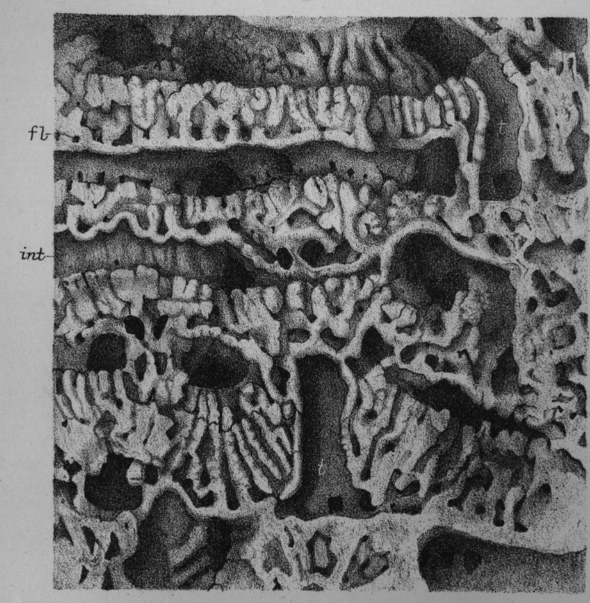
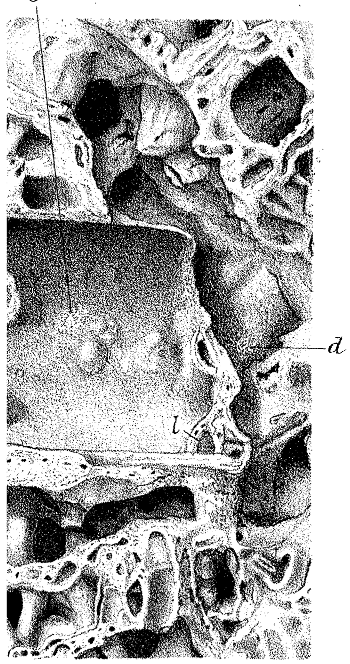
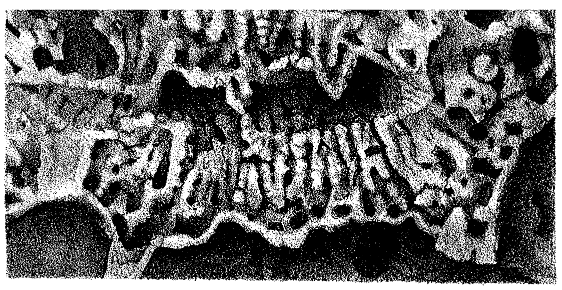


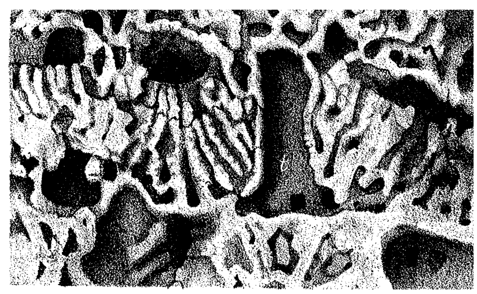
A. Hollick del. et lith. W. West imp.

t

*c*⁵







A.Hollick del. et lith.

W. West imp.

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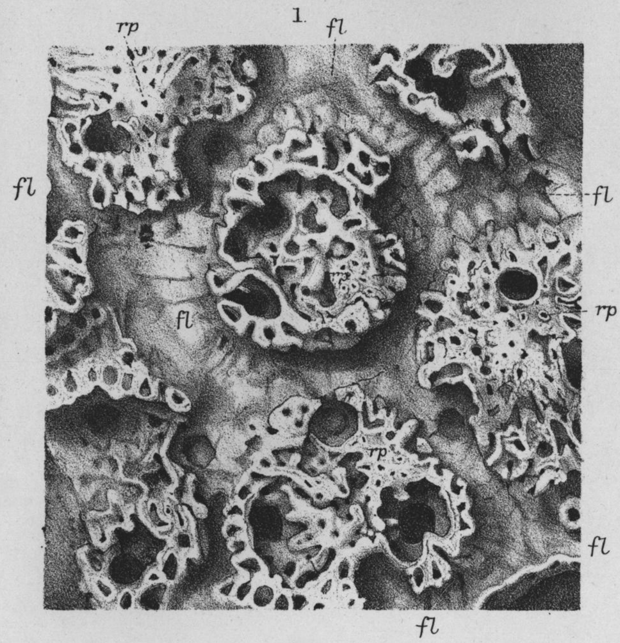
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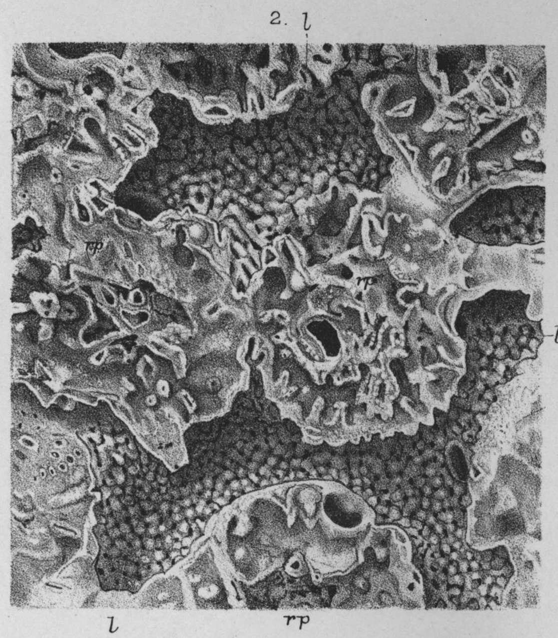
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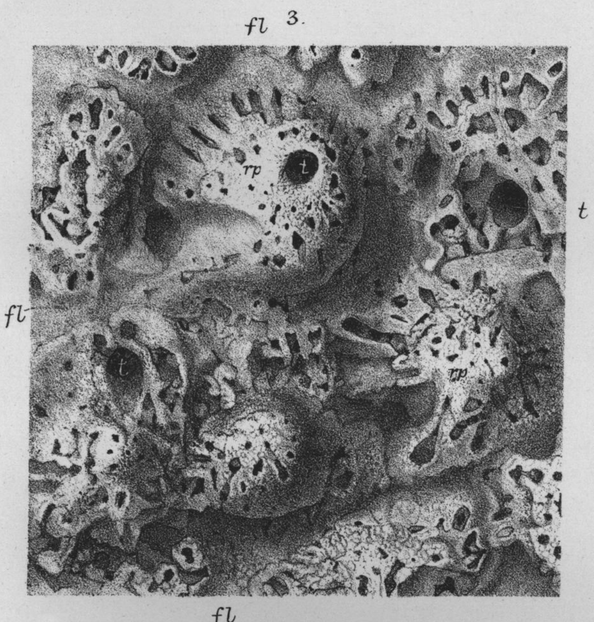
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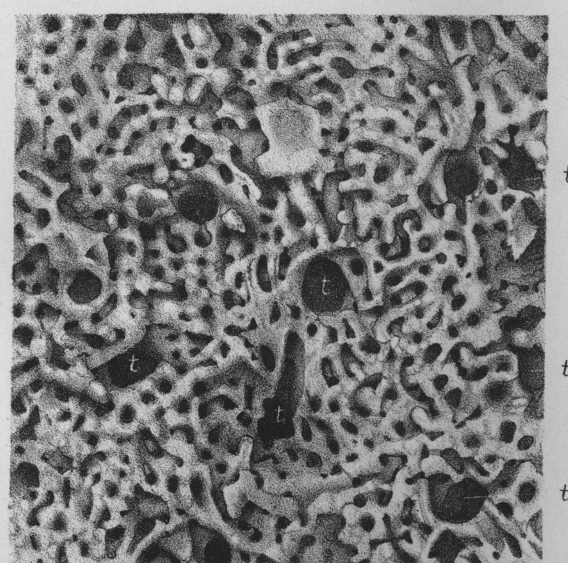
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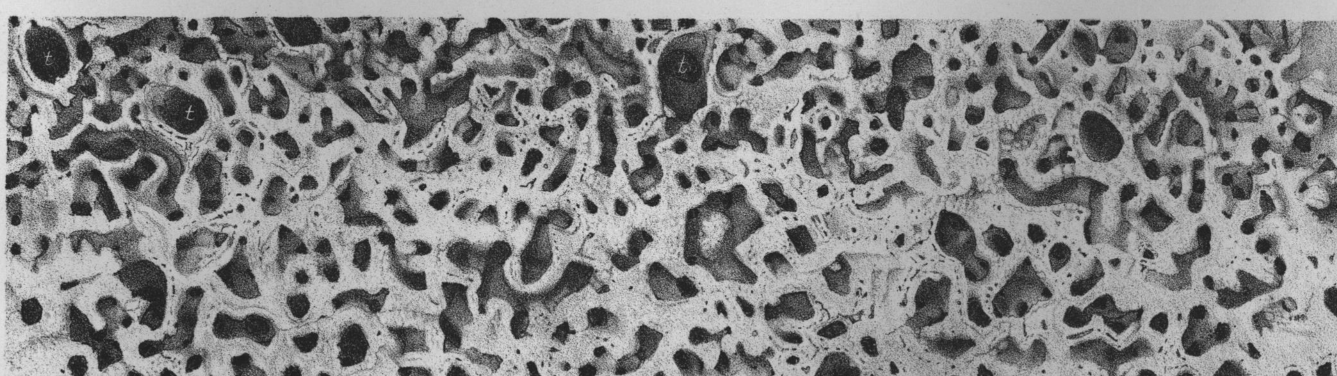
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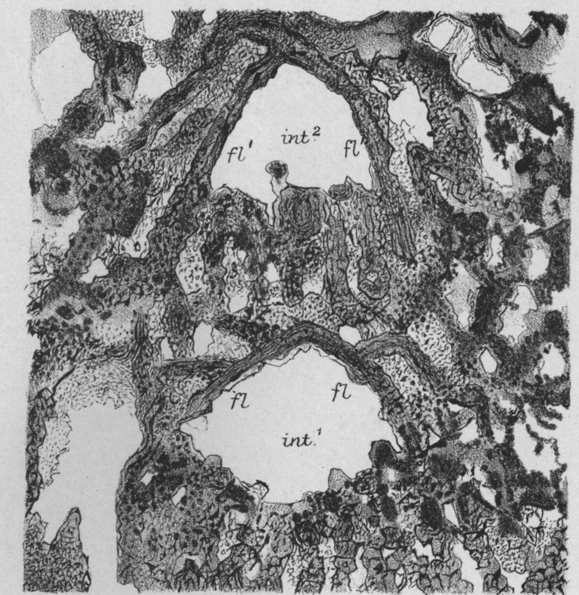

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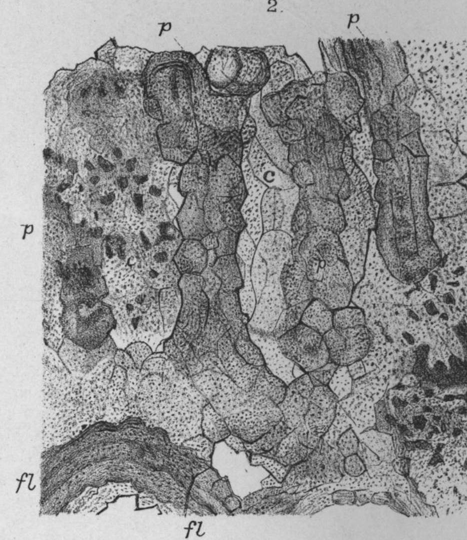

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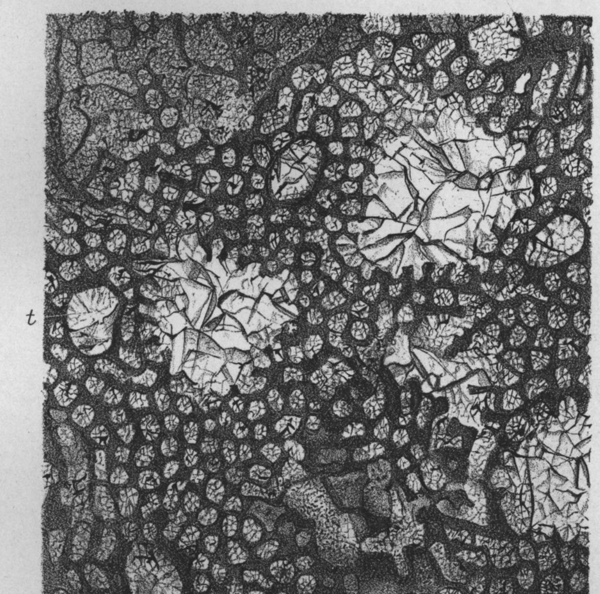

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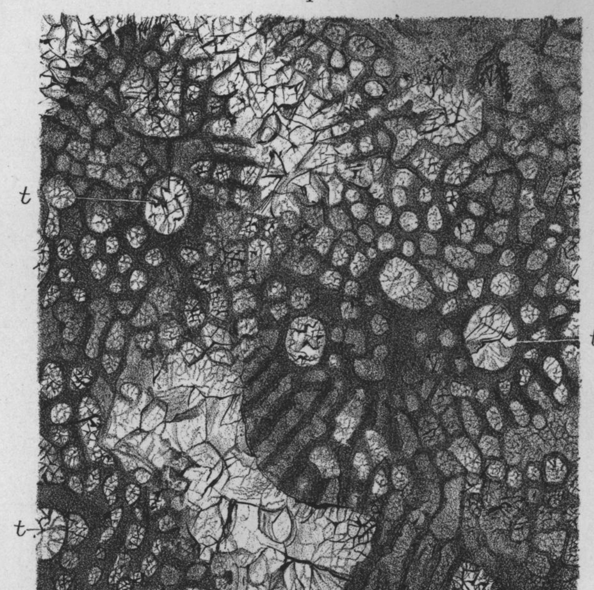

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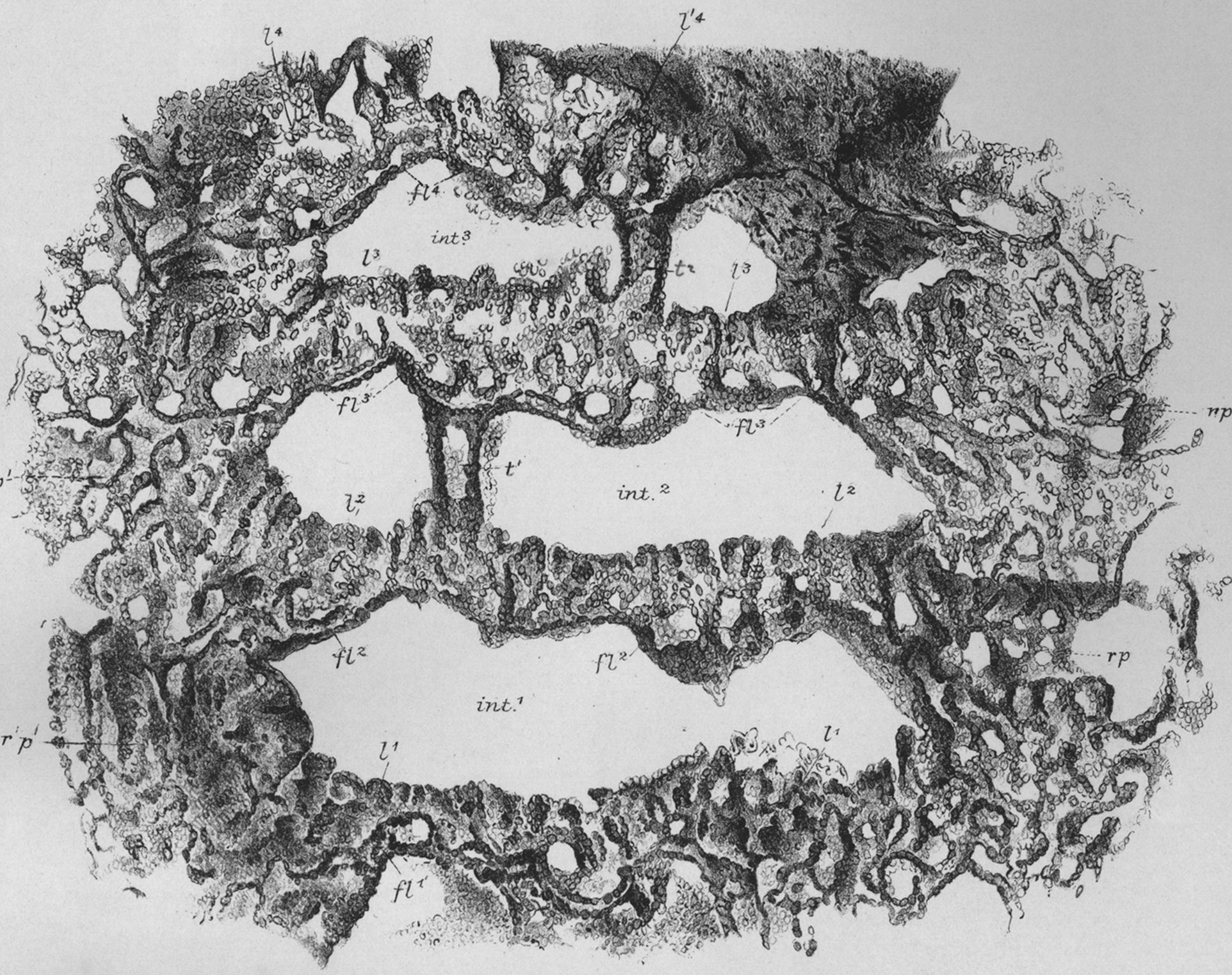

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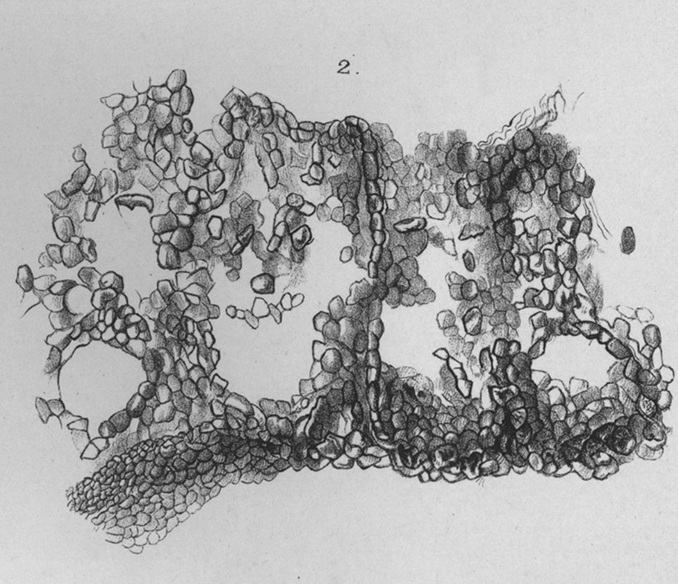

W. H. Wesley lith.

W. West imp.

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3.

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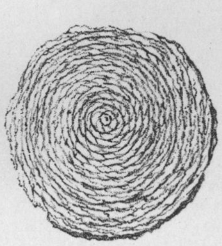

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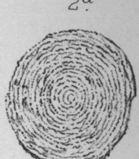

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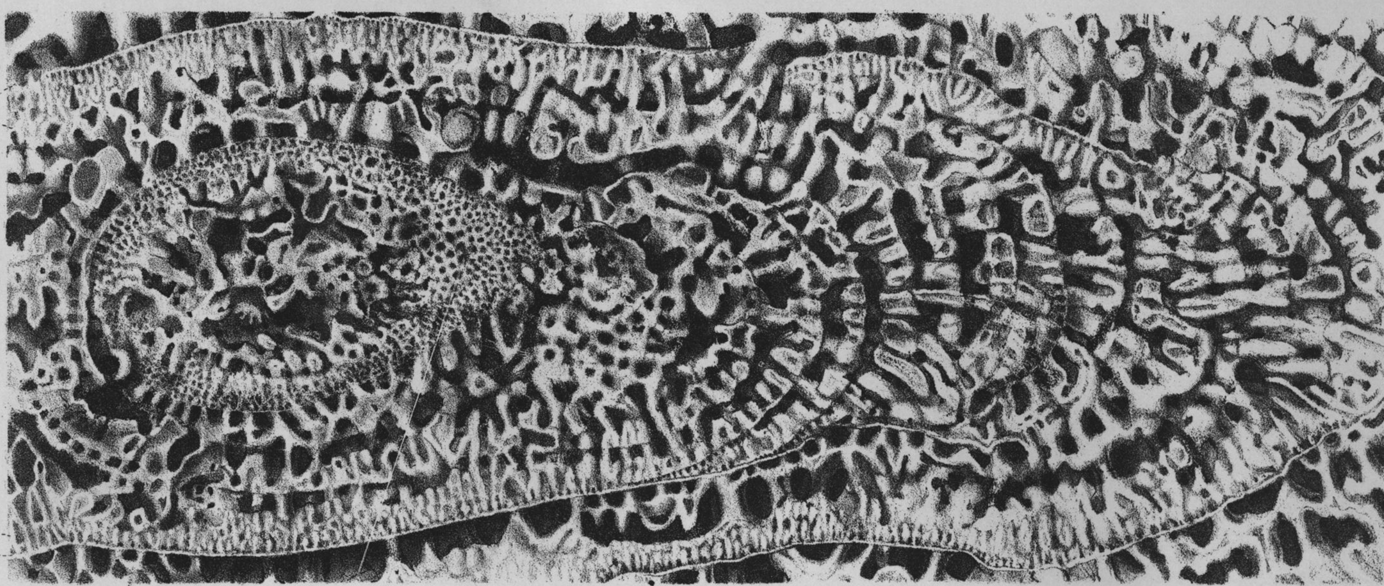
LOFTUSIA PERSICA.

A. Hollick del. et lith.

W. West imp.

1



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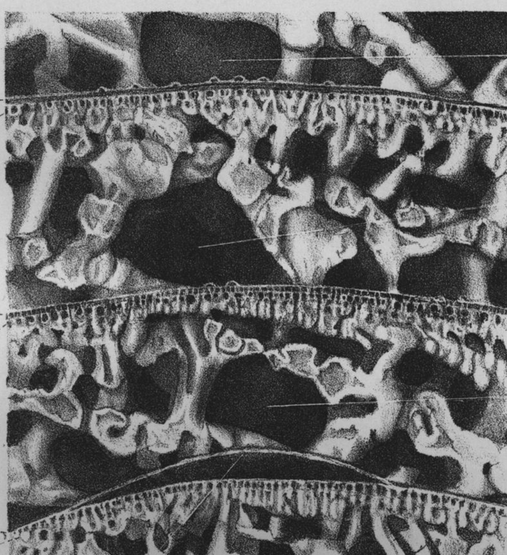

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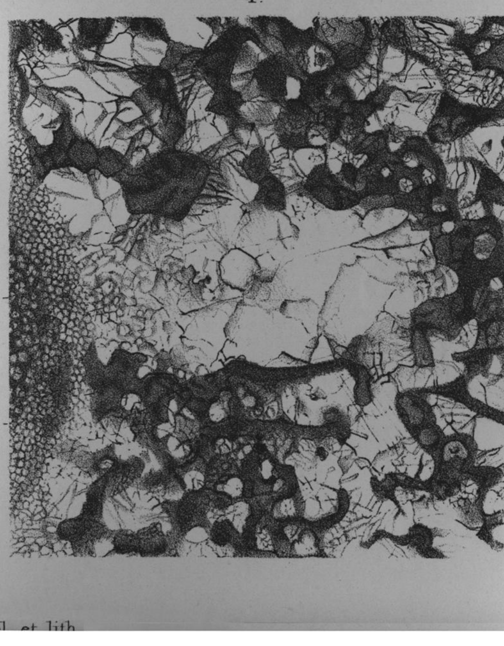

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A. Hollick del. et lith. W. West imp.

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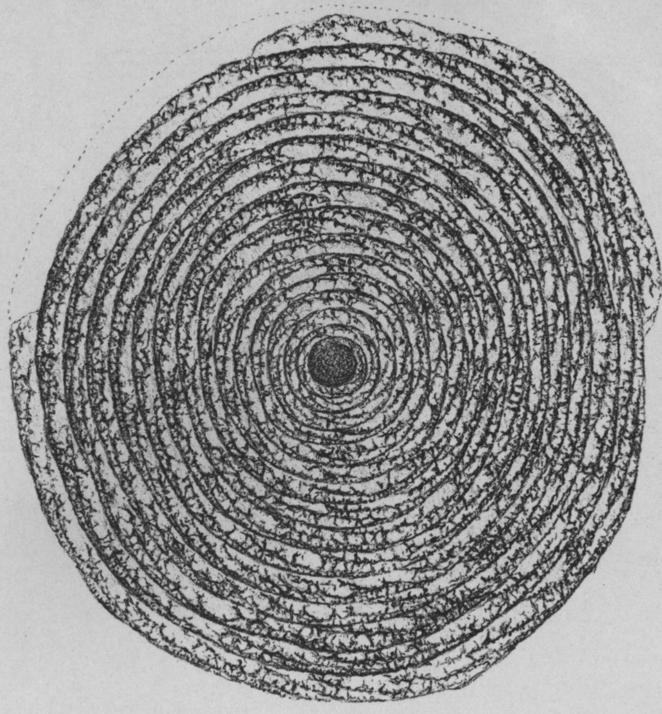

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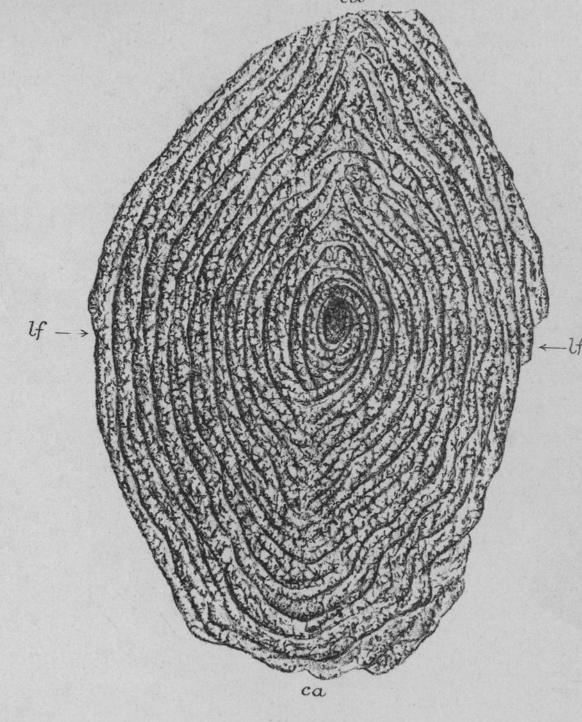

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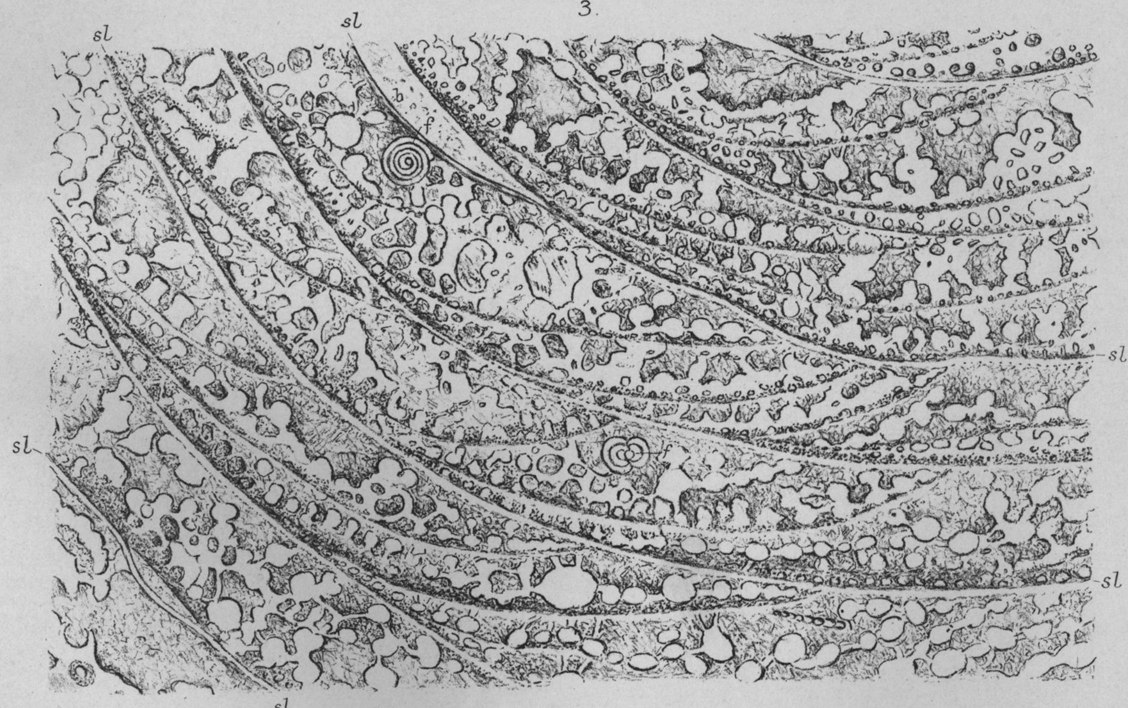

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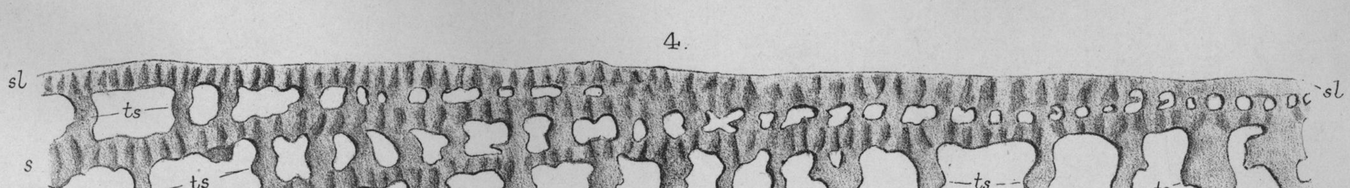

Tuffen West del et lith. W West imp.